

PROJECTS THEORY APPLICATIONS CIRCUITS TECHNOLOGY

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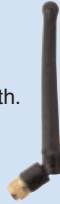
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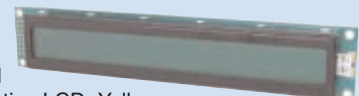
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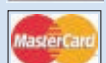
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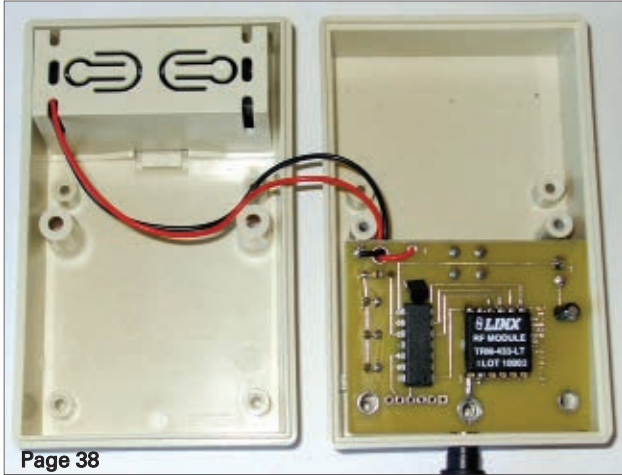
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# Nuts & Volts 2010 November

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## Projects & Features

### 34 Piezoelectric Film Speaker

Experiment with this unique piezoelectric material to see what kind of audio sounds you can produce with film and a little voltage.

■ By John Iovine

### 38 Is Your Garage Door Open?

You'll never have to wonder again with this handy device.

■ By Ron Newton

### 44 Oscilloscope Probes and Probing

As you start probing higher and higher frequencies, often the results get increasingly odder. This article addresses the reasons for that strange behavior. The ultimate solution to the shortcomings of your 10:1 probe is a very expensive Active Probe — but here is one you can construct for \$25.

■ By Robert Reed



Did you know that each article in *Nuts & Volts* has its own webpage? It's where you go for downloads, comments, updates, corrections, or to link to the article in the digital issue. The unique link for each webpage is included at the top of the article.

You can also visit article pages from back issues at [www.nutsvolts.com](http://www.nutsvolts.com). Just select the **Back Issues** tab from the **Magazine** drop down menu, click the Table of Contents link, and the article name.

## Columns

### 10 TechKnowledgey 2010 Events, Advances, and News

A new approach to solar, a new battleground in hacker wars, the world's smallest 64 GB SSD, plus other stuff you'll find interesting.

### 14 The Spin Zone Adventures in Propeller Programming

Lighting Up the Season — Again!

### 24 Q & A Reader Questions Answered Here

Attic fan control, seven-segment LED help, a timer project, plus more.

### 54 The Design Cycle Advanced Techniques for Design Engineers

A Universal Micro Design.

### 60 Smiley's Workshop Programming • Hardware • Projects

Getting a Little Shifty.

### 68 Near Space Approaching the Final Frontier

The Canon Hacker Development Kit — Part 2.

## FUNDamentals For Beginners

Just getting started in electronics? Try these simple demos to illustrate electronics principles and how components function in actual circuits!

### 76 How a PNP Transistor Works

## Departments

08	DEVELOPING PERSPECTIVES	72	NV WEBSTORE
30	NEW PRODUCTS	76	CLASSIFIEDS
37	SHOWCASE	78	TECH FORUM
66	ELECTRO-NET	81	AD INDEX

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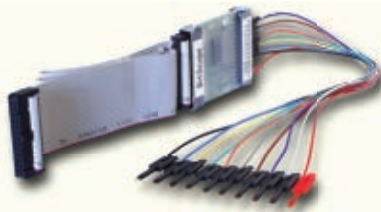
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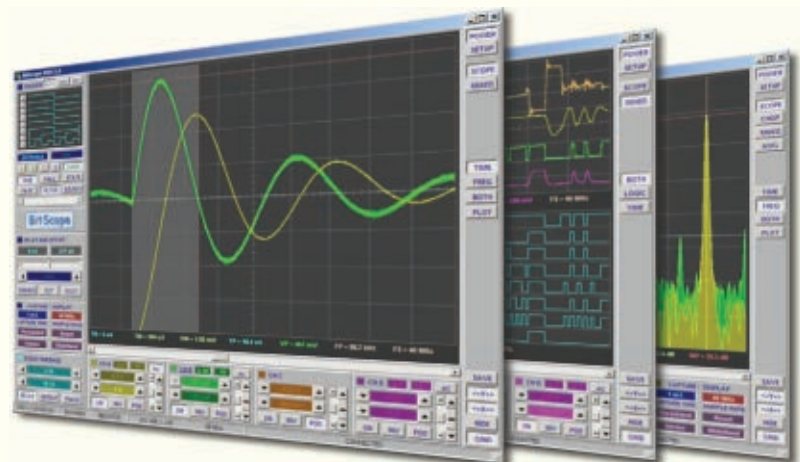
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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## Semiconductor Shortage — Time for Innovation

If you or your company is in the electronics manufacturing business, you're probably aware of the worldwide semiconductor shortage. Apparently, the economic slowdown coupled with a recent increase in demand for consumer electronics caught suppliers off guard. The shortage is especially acute in power management semiconductors which are used in just about everything. As a result, electronics manufacturers are scrambling to develop workarounds, consumers are paying more for some items, and many electronics enthusiasts are simply out of luck. The current situation presents several learning points. One is to keep a supply of basic components on hand so that you don't have to place an order with Digi-Key, Mouser, or some other supplier every time you want to build a circuit. For example, I have several plastic parts containers with common value resistors, capacitors, power regulator chips, switches, microprocessors, and connectors. I've accumulated this supply not to ward off shortages, but because it's time- and cost-effective. As a rule of

thumb, I triple the basic order for whatever parts are required for a project. Given that postage and handling are significant expenses, adding a few extra chips to an order adds greatly to convenience and minimally to overall cost. Another option is to order a few of the bulk component samplers — the bags of 1,000 resistors, capacitors, or other components. It's a quick way to have a ready supply of basic parts on hand.

The second and probably most significant learning point is that it's important to think of alternatives whenever you approach a circuit. Think of the articles in *Nuts & Volts* as basic recipes. That is, they're starting points that you can and should personalize. Instead of approaching a project as 'cookbook electronics' or the equivalent of paint-by-numbers construction, think of ways that you can improve on the basic design. How can you make a circuit more economical? Smaller? More efficient? More general-purpose? For example, let's say you find an article in this magazine or on the web that describes an op-amp circuit powered by two 9V batteries. It's a common shortcut that often doubles the size and weight of a circuit. Instead of following the original design, why not invest an hour in making the circuit work on a single battery? You'll not only

have a smaller, lighter, and less expensive circuit, but you'll learn about op-amps in the process.

Or, let's say a circuit requires a chip that's not available from the online suppliers because of a worldwide shortage. Spend some time on the web looking for equivalent chips or chip sets, and develop an equivalent circuit. Using substitute components might require reworking the circuit board and changing a few components, but you'll really understand the circuit operation when you're done. Sure, one of the greatest rewards of circuit building is applying power and having the circuit come to life. But the deeper, longer lasting reward is gaining an understanding of what's going on in the circuit so that you can apply it to new circuits and situations. With time, you'll develop a repertoire of circuit designs that will not only make you impervious to temporary component shortages but that will enable you to create your own circuits from scratch. Then you'll be the one sharing your expertise with other readers. Happy circuit building.

**NV**



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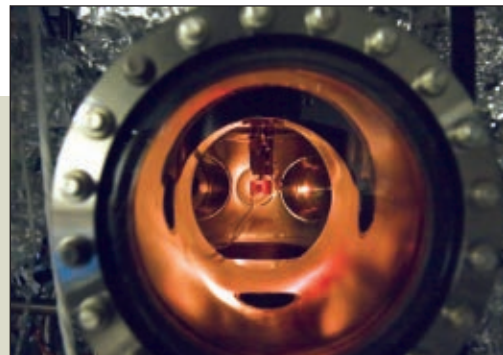
## ADVANCED TECHNOLOGY

### NEW APPROACH TO SOLAR

We've become pretty much accustomed to the steady flow of ho-hum incremental improvements in solar technology, but engineers at Stanford University ([www.stanford.edu](http://www.stanford.edu)) claim to have come up with a process that can more than double the efficiency of solar cell technology and even make it price competitive with petroleum. Called photon enhanced thermionic emission (PETE), it is uniquely able to simultaneously tap into the sun's light and heat.

Most photovoltaic cells use a silicon semiconducting material to convert photons into juice, but they use only a portion of the light spectrum and discard the rest in the form of heat. Unfortunately, such cells become less efficient (and physically degraded) at higher temperatures, so you generally can't boost their output via concentrating devices such as parabolic dishes. (In 2008, IBM demonstrated a system that focused 2,300 equivalent suns on a one sq cm cell to generate 70W, but it required a "liquid metal" cooling system to keep the temperature in check.) In contrast, a PETE device doesn't really hit its peak output until it gets past about 200°C (392°F), so there's no reason why you can't couple one with a thermal conversion system to double the overall output. The new photovoltaic is based on coating a

■ A small PETE device glows inside a vacuum test chamber.

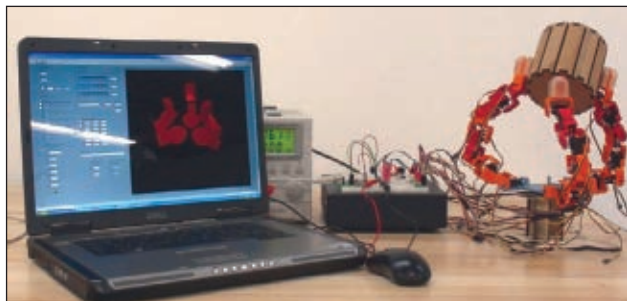


different semiconductor material (in this case, gallium nitride) with a layer of cesium to produce a substance that can handle the high temperatures. The nice touch is that, if properly designed, a PETE system can be retrofitted to existing thermal systems for a relatively inexpensive conversion. According to Prof. Nick Melosh, "This is really a conceptual breakthrough, a new energy conversion process, not just a new material or a slightly different tweak. It is actually something fundamentally different about how you can harvest energy." The materials used in the devices are cheap and readily available, so we're not talking about something that's exotic and cost prohibitive. The only apparent catch is that you probably won't want something sizzling on your rooftop at temperatures as high as 800°C (1,500°C), so the devices will probably be exiled to such places as the Mojave Desert. ▲

### US ARMY DEVELOPING SNAKEBOTS

The desktop prototype may not look like much, but the US Army Research Lab ([www.arl.army.mil](http://www.arl.army.mil)) is expanding on snakebot technology developed at Carnegie Mellon's Robotics Institute that may allow the use of systems instead of soldiers for dangerous search-and-rescue missions, IED disposal, and cargo and checkpoint inspections. The incarnation is the Robotic Tentacle Manipulator, described as an "arrangement of the bases of several snakes in a circular array that functions like a team using multiple parts of their bodies to manipulate an object, scan a room, or handle improvised explosive devices." An interesting aspect is that the system is scalable and therefore can be built as a subsystem to larger platforms such as the iRobot Warrior which is designed to traverse rough terrain and even climb stairs. It is also extensible in that, by varying the number of links on each tentacle, you can adjust its reach and its ability to crawl, swim, climb, or

■ The Army's snakebot will improve maneuverability and autonomy for search-and-rescue and other operations.



otherwise move through narrow spaces. Plus, fitted with a camera, it can simultaneously send images back to the operator. In fact, the subsystem can be equipped with an array of sensors, including LADAR, allowing it to generate 3D images. It even features touch sensitivity which allows it to balance objects and detect applied forces. Researchers are hoping that the manipulator will soon solve the "opening a door problem" — a challenge posed by the variety of knobs, handles, levers, bars, etc., used on doors. Summarizing, an Army rep observed, "This is a distributed intelligence framework that permits advanced manipulation algorithms to run on a complex but affordable hardware platform." ▲



# COMPUTERS AND NETWORKING

## RUGGEDIZED COMPUTER FOR MOBILE WORKERS

One of the newcomers in the computer market is the Marathon™ Field Computer from LXE ([www.lxe.com](http://www.lxe.com)). It doesn't fit easily into any category, as it offers a larger screen and more computing power than the usual PDA, but it's smaller than a laptop and includes a variety of data-capture and connectivity choices. It is also ruggedized for mobile workers in such jobs as route accounting, public safety, and field service management. The Marathon is powered by an Intel Atom processor that runs the full version of Windows 7 or XP, and it includes a seven inch outdoor-visible touchscreen, a QWERTY keyboard, a fingerprint reader that doubles as a mouse, and a high-res color camera. You can also add such things as a mag stripe reader, 2D imager, and extended-life batteries for continuous operation up to 12 hours. The unit employs Qualcomm's Gobi wireless wide area network (WWAN) technology, allowing it to connect to the Internet at 3G speeds, plus a WiFi connection via 802.11 a/b/g/n and Bluetooth connectivity. In addition, it carries an IP-65 rating which essentially means that it is dust-tight, and you can blast it with water from any direction with no harmful effects. The company had not announced the Marathon's price as of press time, but the company's MX3Plus hybrid tablet runs around \$2,500, so plan on going up from there. ▲



■ The Marathon Field Computer, designed for rugged field operations.

## NEW BATTLEGROUND IN HACKER WARS

Most computer security measures tend to focus on protecting personal computers, but the founders of **StopTheHacker.com** want you to know that a big and fast-growing hacker target is websites. Apparently, they are taking advantage of new chinks in Internet security to attack websites which often are minimally protected sitting ducks. According to co-founder Michalis Faloutsos, "Websites are the next battleground in the war for computer security ... We are in the early stages of this war, and any website is vulnerable." One favorite trick is to place difficult-to-detect malware inside your web pages so that a visitor who clicks on a link will be directed to the hacker's site rather than a legitimate destination. The hacker may thereby acquire personal information, upload more malware, or even damage the visitor's system. Malware is even being injected into banner advertisements, PDF files, and other documents that you might encounter while surfing and, unfortunately, antivirus services and firewalls are not up to the task of detecting and dealing with such things.

To combat the problem, **StopTheHacker.com** — with support from the National Science Foundation — has developed a two-pronged strategy. First, they play the role of a potential hacker and ferret out weak points in a client's website, calculating the best way to penetrate those spots. Then, they run periodic scans of the site to verify its integrity. Faloutsos noted, "Our system 'learns' how to hunt down malicious code — unlike the approach taken by the antivirus world where a signature for a specific sample of malware is searched for on a computer. This allows us to identify previously unseen malicious code and analyze new emerging threats."

The good news is that the **StopTheHacker.com** approach is based on the belief that security should not be the concern of the customer but is "the inherent responsibility of the hosts." The bad news is that you need to talk your web host into signing up. ▲



■ StopTheHacker.com's vision of cybersecurity.

*Photo courtesy of Zina Deretsky, National Science Foundation.*

## ARE YOU A NARCISSIST?

Are you a narcissist? Do you suffer from low self-esteem? Better analyze your Facebook account to find out. According to an undergrad thesis by Soraya Mehdizadeh, a psych student at Toronto's York University ([www.yorku.ca](http://www.yorku.ca)), people with such personality defects tend to use Facebook as a self-promotional tool and are among the heaviest users of the site. For purposes of the study, "self-promotion" was defined as "any descriptive or visual information that attempted to persuade others about one's own positive qualities." Other indications of potential psychopathy include "use of positive adjectives, self-promoting mottos, and metaphorical quotes," striking a pose or making a face in your photo, or using photo editing software to hide the wart on your nose. For example, on one site I recently visited (discretion prevents me from divulging the person's name), one obvious swellhead said, "I'm so smart that I figured out a way to get college credit for playing around on Facebook."

But all is not gloom and doom here. Mehdizadeh offers us hope of salvation: "I believe the next question to be answered is whether or not the use of such websites could be used to improve one's self-esteem and overall sense of well-being. This sort of finding may have great implications in the lives of the socially anxious or depressed." Well, I'm feeling better already. ▲

## CIRCUITS AND DEVICES

### NICE BUDS, BUD

The Ultimate Ears unit of Logitech ([www.ultimateears.com](http://www.ultimateears.com)) has been selling in-ear monitors for musicians and audiophiles for some time, but the latest is a set of reference monitors aimed at professional producers and audio engineers. The product was developed in cooperation with EMI Music's Capitol Studios, so quite a bit of industry experience went into them. Like all studio speakers, the Ultimate Ears In-Ear Reference Monitors provide flat phase and frequency responses to give an uncolored reproduction of the actual recording. This is not necessarily what the average stereo buff wants to hear, so keep that in mind before you consider buying a pair. If all you want to listen to is the natural and true audio track, however, this may be the way to go. The monitors provide up to 32 dB of noise isolation and can reproduce frequencies from 5 Hz to

■ The Ultimate Ears Reference Monitors provide a flat response from 5 Hz to 18 kHz.



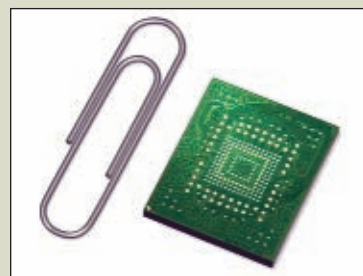
18 kHz. They also employ a tightly braided cable that reduces friction and tangling, as well as reducing crosstalk. A dual sound channel configuration keeps low, mid, and high frequencies separated until they go into your ears, where they "mix naturally, reducing any chance for distortion."

You can't just drop by Walmart and pick up a pair, as each set is made specifically for the customer. You are required to have ear impressions made by an audiologist and sent to the company.

Oh, yeah. One more thing. They cost \$999. Maybe you'll be dropping by Walmart after all. ▲

### WORLD'S SMALLEST 64 GB SSD

You won't be buying one yourself, as it's intended to be embedded in various mobile computing platforms, but it's still noteworthy that SanDisk Corp. ([www.sandisk.com](http://www.sandisk.com)) has introduced an integrated solid-state drive (iSSD) said to be the first high-capacity product in that category. According to the company, it's the first Flash SSD device to support the SATA interface in a small BGA package that can be soldered onto any motherboard, and that is fast enough for use with advanced operating systems in next-generation equipment. The chip offers 160 MB/sec sequential read and 100 MB/sec sequential write speeds, weighs less than a gram, and measures only 16 x 20 x 1.85 mm. Compatible with all standard operating systems, it is available in capacities ranging from 4 to 64 GB. Pricing, as always, depends on quantity. ▲



■ The SanDisk iSSD Flash drive is smaller than a postage stamp and weighs less than a paper clip.

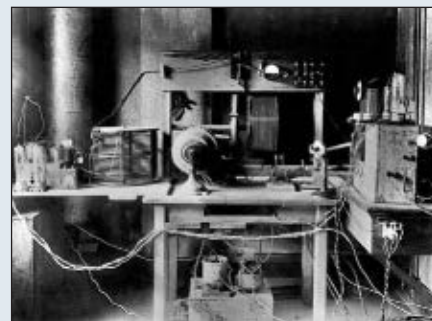
## INDUSTRY AND THE PROFESSION

### STUDY REVEALS WIND POWER MARKET

If you're involved in the wind power business, you may be interested in the latest report on the subject from the D.O.E. and Lawrence Berkeley National Lab. The 2009 edition of the *Wind Technologies Market Report* provides a comprehensive overview of developments in the rapidly evolving US wind power market, which is second only to China in size. For a free download, just point your browser at [www.jkeckert.com/freedownload/2009wind.pdf](http://www.jkeckert.com/freedownload/2009wind.pdf). **NV**

### 90TH ANNIVERSARY OF COMMERCIAL RADIO

It seems like only yesterday, but it was actually 90 years ago (November 2, 1920) when the first commercial radio station went on the air. An experimental version had actually existed in Westinghouse engineer Frank Conrad's garage since 1916 as amateur station 8XK, but it was eventually moved to a shed atop the K Building of the Westinghouse East Pittsburgh works and licensed as KDKA. The first broadcast provided election night coverage (Harding beat Cox, by the way) from 6:00 PM until noon the following day. Between news and occasional music, announcers asked the audience, "Will anyone hearing this broadcast please communicate with us, as we are anxious to know how far the broadcast is reaching and how it is being received." Contrary to rumors, Larry King was not on hand for the occasion. ▲



■ Frank Conrad's 75W experimental transmitter setup.



THE ORIGINAL SINCE 1994

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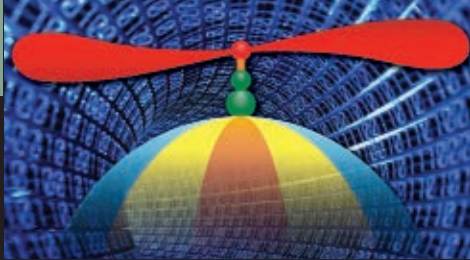
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■ BY JON WILLIAMS

# LIGHTING UP THE SEASON - AGAIN!

I like this time of year. The air is clear (even in Los Angeles!), the mornings are crisp, and the evenings are brightened with holiday decorations that illuminate the insides and outsides of homes everywhere. My home is somewhat small, so my lighting projects are, too. Small doesn't make me wimpy, though, and my little 12-channel lighting board for the Propeller Platform is designed to be tough enough for applications that go way beyond LEDs.

## THE POWER OF 12

A couple months ago, I had the pleasure of working with a leading Hollywood special effects designer to add lighting to a big prop he built for a client. The prop is a futuristic soldier in a large suit that has rocket engines on the back. My friend wanted to use very bright RGB LEDs in the rockets so that they could be faded up to bright red, then slowly transition to blue — all while appearing to pulsate and "rumble" as a real rocket engine does.

Output control was pretty easy as I'd previously used a TIP125 in a high side driver circuit for high power LEDs. I simply whipped up a 12-channel board to handle the "rockets" and other lighting tasks, and then took advantage of launching multiple Spin cogs in the Propeller to simplify the code for each element of the prop. In the end, my friend was very happy — so much so that he was actually making engine sounds with his mouth after we got the code adjusted just the way he liked it!

After buttoning up that project, I started thinking about some holiday lighting ideas and then I had a thought: If I beef up that circuit — just a little — I can use it for other things, too. With 12 channels, I could control 12 independent devices, or I could dedicate three channels

to an RGB LED module, or I could dedicate four channels to control a stepper motor, or I could control any combination thereof. As my friend, John, says, "It's just SMOP" (small matter of programming).

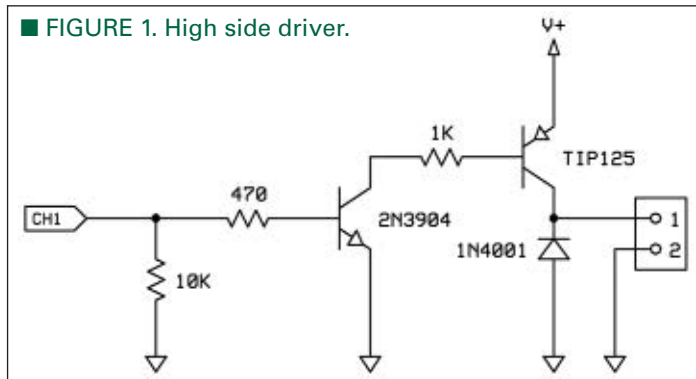
As I was already using a TIP125 which can handle a fair bit of current, I updated the driver circuit (**Figure 1**) by adding a diode across the output terminal; this will let the board handle inductive loads, too. The real trick, though, was squeezing 12 of these circuits onto a standard Propeller Platform module and running power traces on the top and bottom of the PCB (printed circuit board) to increase current capability of the board. That said, the total current should be limited to 5A and only if power is coming in on TB13 (when power is "borrowed" from the Propeller Platform, the connections/traces from the P/P to the driver board cannot carry that much current).

**Figure 2** shows a completed board (with 12V test LEDs attached). Yes, it's pretty busy and will take a little patience to build; just take your time with the components and start with the shortest (resistors) and work your way up to the tallest (TIP125s). As suggested above, TB13 is available when you need to control a lot of power. You can also power the Propeller Platform from TB13 — there are power jumpers to the VIN headers that need to be installed for this. Note, though, that the power switch on the Propeller Platform is bypassed when power from TB13 is shared through these jumpers.

With the little room I had left, I squeezed two simple circuits onto the board. The first (shown in **Figure 3**) is a simple pushbutton and normally open, dry contact input. As with the output circuit above, there is a pull-down on the I/O pin (that is part of a SIP package). The pull-down is especially important on the output circuits to hold the outputs off while the Propeller is in reset and the I/Os are floating.

The other circuit I added is a TTL serial port shown in **Figure 4**. The 2.2K resistor in the RX line allows 5V systems

■ **FIGURE 1.** High side driver.





to be connected without problems; this header can also be used with a standard IR sensor for remote control. (I did this with the "rocket man" prop — it was fun!)

Oh! Before I forget, there is one final note on assembly: The 10K SIPs are intended to go on the bottom side of the board (Figure 5); this keeps them clear of any wiring entering the terminal blocks.

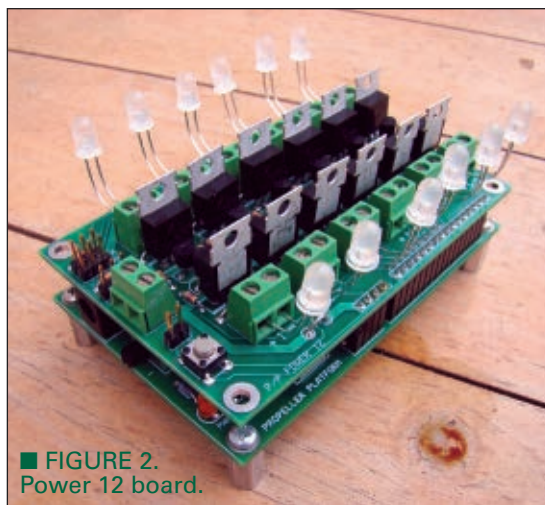
## ELECTRONIC MENORAH REDUX

With 12 channels of control at our disposal and a holiday season just begging for cool lighting projects, let's jump right in — it's just a small matter of programming, right? First up is a do-over of a BASIC Stamp program that I wrote for my column four years ago: an electronic Menorah.

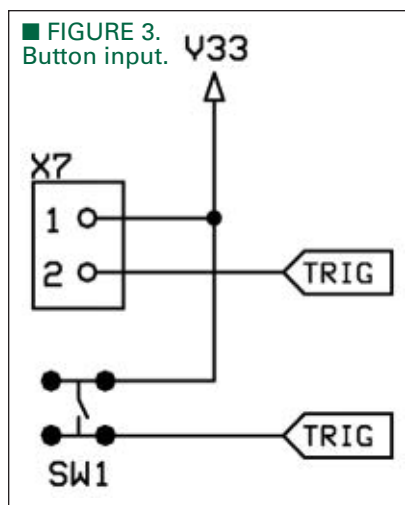
With the BASIC Stamp version, we used a capacitor on the output to smooth a random pulse to the LED to [well, sort of] mimic the flame effect. With the power of the Propeller, we don't need to do that any more, and we can get more realism to boot. In the October '10 issue of *Nuts & Volts*, there is an article that shows how to simulate candle flames with the Propeller; we're going to borrow some of that code and build the Menorah program from it.

In the BASIC Stamp version, we simply turned it on and it would light the candles for the current day (which was incremented at each power-on cycle and stored in the EEPROM). This meant that you had to light it on the first day and not miss any days in between. For the update, I wanted an easy way to select the day at random and to allow manual control over lighting each "candle."

While watching my test LEDs flicker, I remembered a program that I wrote in 1995 for a BASIC Stamp 1 user. He was a pilot and owned a small airstrip. What he asked me to create was a program that could count the number



■ FIGURE 2. Power 12 board.



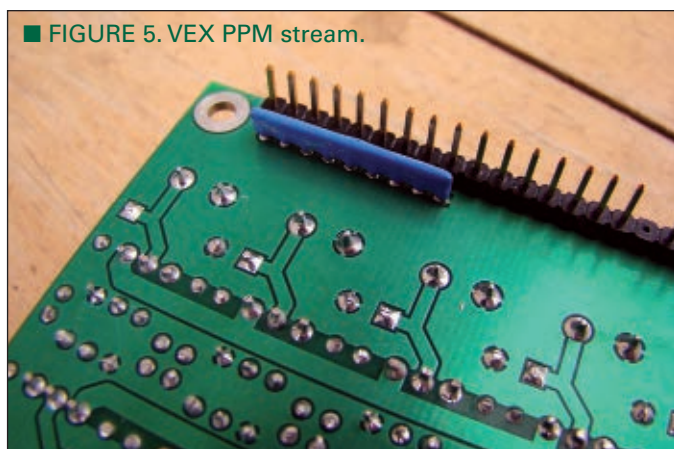
■ FIGURE 3. Button input.

of microphone "clicks" coming through his air-to-ground radio system. The clicks count would be used to activate a relay to turn on the runway lights. The idea was to look for a specific number of clicks in a defined timeframe so that standard radio communications would not trip the circuit.

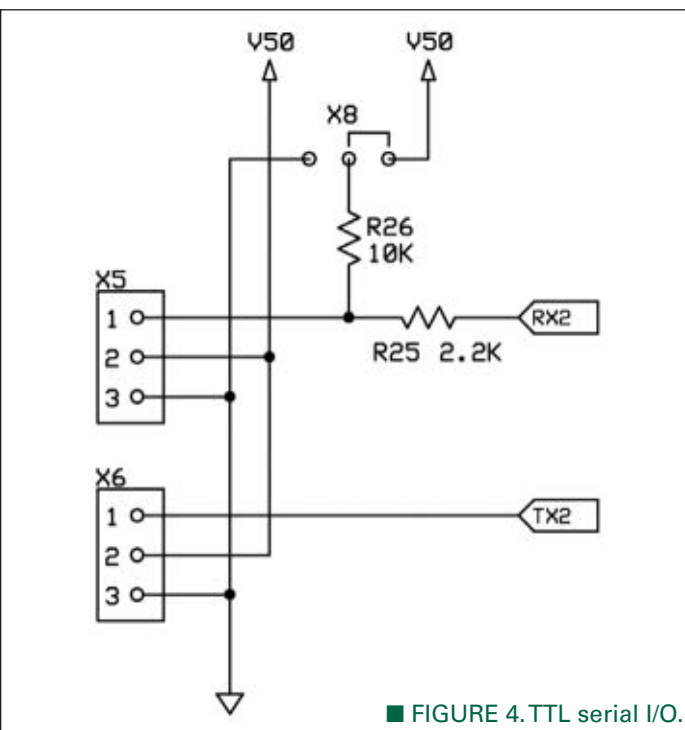
In case you're wondering, yes, it worked. We used a 555 to one-shot the audio pulse which allowed the BASIC Stamp 1 to detect it. With the Propeller, we can do the same thing in software.

Since the Power 12 module has a button on it, this seemed like a good way to go; we can start the sequence (indicated by a lit Shamash candle) by pressing in the current day (1 to 8), and then subsequent presses will light the next candle. By using the secondary presses, the ceremonial blessings can be recited between each candle.

*(Please note: I am not Jewish and do not know if an electronic Menorah is valid for the Hanukkah ceremony.)*



■ FIGURE 5. VEX PPM stream.



■ FIGURE 4. TTL serial I/O.



Please consult with your Rabbi if you have any concerns in this regard.)

I actually developed two helper routines for the button input. The first simply debounces a specified input pin for a number of milliseconds; if the button is pressed through the entire cycle, then it is considered good. Here's that bit of code:

```
pub getbutton(pin, dbtime) | db, t

  dira[pin] := 0
  db := 0

  t := cnt
  repeat dbtime
    waitcnt(t += MS_001)
    if (BTN_MODE == ACTIVE_HIGH)
      db += ina[pin]
    else
      db += !ina[pin] & %1

  return (db == dbtime)
```

We start by forcing the desired pin to an input state and clearing a variable that will count the number of active cycles through the loop; if the active cycles match the specified debounce time, then the button is considered pressed.

Within the loop, we wait one millisecond (synchronized, so as not to add too much overhead for long debounce periods) and then add the state of the input to the counter. Note that the code can accommodate active-high and active-low inputs. In my experience, the buttons on a given project tend to use the same active state so I set that state (**BTN\_MODE**) in the constants section.

At the end of the loop, we return **true** or **false** depending on whether or not the button remained pressed through the entire cycle. This code is very modular and provides a fixed delay that we will use in the following method:

```
pub getcount(pin, cmax) | count, idle

  count := 0
  idle := 0

  repeat
    if (getbutton(pin, 50) == true)
      repeat
        until (getbutton(pin, 50) == false)
        count += 1
        idle := 0
      else
        idle += 50

    if (count == cmax)
      quit

    if (count > 0) and (idle ==> 1000)
      quit

  return count
```

Again, the purpose of this method is to count the number of presses on the target input pin, up to a specified maximum. It uses the **getbutton()** method to scan the pin and create internal timing.

At the top, we clear the button count and idle timer variables. When a button press is detected, the code waits for it to be released, increments the count, and then resets the idle timer. If there is no button press, then the idle timer is incremented by 50 since that is the timing used with **getbutton()**.

There are two ways to return from this method: 1) The maximum button count is reached, or 2) There is a non-zero count and the button has been left idle for at least one second (1,000 ms). I considered passing the maximum idle time as a parameter, but it really didn't seem to be worth doing. I spent a lot of time playing with this method and it works quite well. That said, you may need to fine-tune it for different buttons as some are easier to press than others.

Now we can create the working Menorah code:

```
pub main | day, level

  leds.init(360)

  bytefill(@wicks, 0, 12)
  cognew(flicker(9), @stack)
```

At the top, we initialize an object called **leds** — this is a 12-channel BAM driver that is set up especially for the Power 12 PCB, so the only thing we have to specify is the desired modulation frequency. The next step clears the array called *wicks* that will hold our candle brightness values. Finally, we launch the candle flicker generator into its own cog using **cognew** (this is discussed in detail in the October '10 issue).

The next step is to get the day number from the user and then light the Shamash ("helper") candle:

```
day := getcount(TRIG, 8)

repeat level from 0 to 255
  wicks[8] := level
  pause(6)
```

The current day is entered with the **getcount()** method which — for a Menorah — is limited to eight. After returning from **getcount()**, we light the Shamash candle which is on channel nine (P8) of the Power 12 board. A six millisecond delay between each brightness level causes the "candle" to be fully lit in about a second and a half.

The next step is to light each candle in order, starting with the current day. A button press is required for each candle so that there is time for the recitation of blessings between each:

```
repeat
  pause(1000)
  repeat
    until (getbutton(TRIG, 50) == true)
    repeat level from 0 to 255
      wicks[day-1] := level
      pause(6)
    if (--day == 0)
      quit
```

Within the loop, we allow the last candle to "burn" at least one second before scanning the button for a new press. When this is detected, the candle for the day is "lit"



just as we did above. The day indicator is then decremented to point to the next candle. When all are lit, we can quit the **repeat** loop.

The last step is to wait for one more press — this time, to extinguish the candles. While I found a lot of good information regarding the lighting sequence of the Menorah, I never came across anything having to do with extinguishing the candles. This routine, then, will very slowly dim all at the same time:

```
repeat
until (getbutton(TRIG, 250) == true)

repeat level from 255 to 0
  repeat day from 8 to 0
    if (wicks[day] > 0)
      wicks[day] := level
    pause(24)
```

Note that we require a longer button press to extinguish the candles. This is by design to prevent an accidental bump of the button from extinguishing them too early. Note, too, that the loop timing for the fade-out is longer to create a nice, slow fade-out.

So, there you have it: a Propeller powered electronic Menorah. I think you'll find the code easy to modify and the candle simulation is far nicer than the old RC circuit. You can find the complete program in the downloads package as *jm\_pp12\_menorah.spin*.

## THE KWANZAA KINARA

Before we move on, there is another, multi-day holiday celebration that uses a special candelabra: Kwanzaa. Those that celebrate Kwanzaa light the Kinara which has seven candles (one for each day). Since the Kinara candles are lit in ascending order each day, the code is a little simpler.

That said, I employed a little trick in this program to show you how to re-map outputs when they are not in the desired order. Let's say, for example, that we built a beautiful electronic Kinara and wired it with the outputs connected to each candle, moving left to right, in ascending order, like this:

1 2 3 4 5 6 7

The problem is that the Kinara candles are lit in this order:

2 4 6 1 7 5 3

In the event we can't (or don't want to) rewire the project, we can remap the outputs with a simple table in Spin. Here's a little table I created to remap the (zero-indexed) day to the physical channel output on the board:

dat						
kinara	byte	3,	0,	6,	1,	5, 2, 4

On the first day (0), we will light the center candle (black) which is connected to P3. On the second day, we

will light the outermost red candle which is connected to P0. The map should now make sense.

Here's the core code for the Kinara:

```
repeat
  repeat
  until (getbutton(TRIG, 100) == true)
  pause(250)
  if (getbutton(TRIG, 150) == false)
    if (day < 7)
      idx := kinara[day]
      repeat level from 0 to 255
        wicks[idx] := level
        pause(6)
      ++day
    else
      repeat level from 255 to 0
        repeat day from 6 to 0
          if (wicks[day] > 0)
            wicks[day] := level
          pause(24)
        quit
```

At the top, we have a little trickery concerning the button input. Since the Kinara candles are lit in ascending order and always start with the central candle, the program doesn't know what day it is — we tell it with each new press. What we do, then, is scan the button, wait a bit, then check again (note these periods are slightly longer than before). The idea is that a short button press will light the next candle and a long button press will extinguish those that are lit.

You can see that we treat the **dat** table like a simple array, reading the correct output for the day that we're presently lighting. Easy, right? I think so — and, it's definitely easier than rewiring a project.

See *jm\_pp12\_kinara.spin* for the complete, commented listing.

For those that are interested in building a fully functional Menorah or Kinara, I again encourage you to consult the October '10 issue as there are detailed instructions on building candles from LEDs and items that you can pick up at any hardware store.

## PLAYING WITH PROTOCOLS

More and more of those home Christmas displays that I enjoy so much are coming under computer control. I think a good chunk of the credit goes to a nifty bit of freeware called Vixen which was developed and maintained by my friend, KC Oaks.

If you're new to this stuff and really want to dive into the fray, I suggest that you check out **www.doityourselfchristmas.com**. It's a very active set of forums with many knowledgeable, highly enthusiastic members.

One of the more popular protocols supported by Vixens and a favorite with many DIY Christmas lighting enthusiasts is called Renard, which was created by a gentleman named Phil Short. Most of the code on the 'net for the Renard protocol is PIC-based as that's what Phil uses, though I have seen an implementation done in SX/B.

The Renard system is typically set up such that one

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X1-X8	0.1 M-STRT	Mouser 517-6111TG*
PCB		ExpressPCB

\* The 517-6111TG is a 40-pin component; only two are required for the project (split as needed).

board receives the packet from an upstream device (console or another unit) and uses the bytes intended for this board while retransmitting all others. I believe this design was intended to create a plug-and-play, auto-addressing scheme. You see, each controller is looking for a specific two-byte sequence at the start of its data:

```
$7E $80 <dimmer data>
```

If we had two controllers in the system, we would see something like this from the console:

```
$7E $80 <aaaaaaaa> $7E $81 <bbbbbbbb>
```

In the Renard system, the packet that follows \$80 is consumed locally and not retransmitted. When the second address byte is (\$81) received by the first controller, it is decremented to \$80 which enables the second packet for the second controller. Downstream of the first controller, the stream above becomes:

```
$7E $80 $7E $80 <bbbbbbbb>
```

As you can see, the first packet of dimmer values is removed and the second address is decremented such that it will be recognized by the second device in the chain. The second device isn't bothered by the missing packet data; the new SYNC byte that follows the address byte resets everything internally.

With the large base of users, one can only assume that the system has proven itself. My question became, can I create a half-duplex (receive-only) device that would work with the protocol? I think the answer is yes and I'm going to show you what I did. From my view of the world, the Renard protocol has three major states:

- Wait for sync byte (\$7E)
- Wait for address byte (\$8x)
- Process packet bytes

To send the SYNC value as a dimmer level, it gets encoded as two bytes: \$7F, \$30. What this means, then, is that we need two-byte encoding for a \$7F (ESC) dimmer level — that would be \$7F, \$31. Finally, there is a "pad" byte that may be sent by the console that is ignored by the Renard device. To use the PAD value (\$7D) in the dimmer packet, it gets encoded as \$7F, \$2F.

Okay, then, let's give it a whirl. For most serial applications, we can use the FullDuplexSerial object to do the heavy lifting. Yes, we only need half duplex (reception) for this project but FDS is still just fine. To set up FDS, we will typically do something like this:

```
console.start(RX1, TX1, %0000, 115_200)
```

The serial object is called "console" and we're going to receive at 115.2K baud on pin RX1 (the programming port to make testing easy). The third parameter is the mode; in this case, we're going with the standard true mode which works with RS-485 devices, as well as USB-serial devices like the Prop-Plug and the USB2SER.

And now for the fun! What I did is set up a simple state handler to accommodate the rules defined for the Renard protocol. Again, my code is just a "sniffer" (that is, it doesn't retransmit anything) so it will be looking for an address that could be something higher than \$80 (which it must be if there are standard Renard devices in use on the same buss):

```
console.rxflush
state := W_SYNC
chan := 0

repeat
  cmd := console.rx
  case state
    W_SYNC : if (cmd == SYNC)
              state := W_ADDR
```

This is the basic setup and handling of the first state. The receive buffer gets flushed after the serial object is started just to make sure that there's no garbage in it. After initializing the state and chan variables (which are local to the method therefore must be manually initialized), we drop into a **repeat** loop that will execute the state handler.

At the top of the loop, we receive a byte from the console and drop into a **case** structure. The first task is to look for the SYNC byte. When that happens, we can advance the state to look for the address byte that matches our board:

```
W_ADDR : if (cmd == PAD)
          ' ignore
        elseif (cmd == SYNC)
          ' no change
        elseif (cmd == ADDR)
          state := W_LVL1
          chan := 0
        else
          state := W_SYNC
```

In the W\_ADDR state, the program is waiting for the address byte, but other values could arrive and we need to handle them. If a PAD (\$7D) byte or another SYNC byte arrives, there is no change in state. If the correct



address byte arrives, then the state is bumped to start reading dimmer values from the stream and the channel pointer is reset to zero. If any other value arrives, we reset the handler and wait for the next SYNC byte:

```
W_LVL1 : if (cmd == PAD)
    ' ignore it
elseif (cmd == SYNC)
    state := W_ADDR
elseif (cmd == ESC)
    state := W_LVL2
else
    leds.set(chan, cmd)
    if (++chan == CHANNELS)
        state := W_SYNC
```

In most cases, the packet will arrive very cleanly but, as we did above, we need to handle any exceptions, as well. If a PAD byte comes, we ignore it. If a new SYNC byte shows up, then we reset the state processor to look for the board address. If an ESC byte arrives, then the channel value is encoded as two bytes and we update the state handler to process the second byte.

Finally, if none of that happens, we simply take the new byte as the current channel value. After updating the dimmer, the channel count is incremented and when we've reached the limit for this board, the state is reset to start the process for the next packet.

For those dimmer values that are encoded with two bytes, the W\_LVL2 state handles the second byte and updates the dimmer channel:

```
W_LVL2 : if (cmd == $2F) and
    (cmd <= $31)
    cmd := $7D + (cmd-$2F)
    leds.set(chan, cmd)
    if (++chan == CHANNELS)
        state := W_SYNC
    elseif (cmd == SYNC)
        state := W_ADDR
    else
        state := W_SYNC
```

If the second byte is in the correct range (\$2F to \$31), the dimmer value is calculated and the LED channel is updated. As above, the channel count is checked and if the value just received is for the last channel, the state processor is reset.

If we happen to get a "broken" packet and a new SYNC byte shows up, we go back to looking for the address byte. Otherwise, we go back to looking for the

next SYNC byte.

Whew! I know that reading about that process probably makes it seem more difficult than it is. Once you see the full listing (in *jm\_pp12\_renard\_ez.spin*), it will be easier to grasp. Does it work? Absolutely! And, I blasted packets at it all day long at 115.2K baud (most Renard systems run at 57.6K or slower). **Figure 6** shows my Vixen test pattern that I sent to the board during testing. Every time I looked in on it, the pattern was happily running on the LEDs, so the trouble we took to make the state handler robust seems to have paid off.

Get Your Hands On What's Next.



Scan

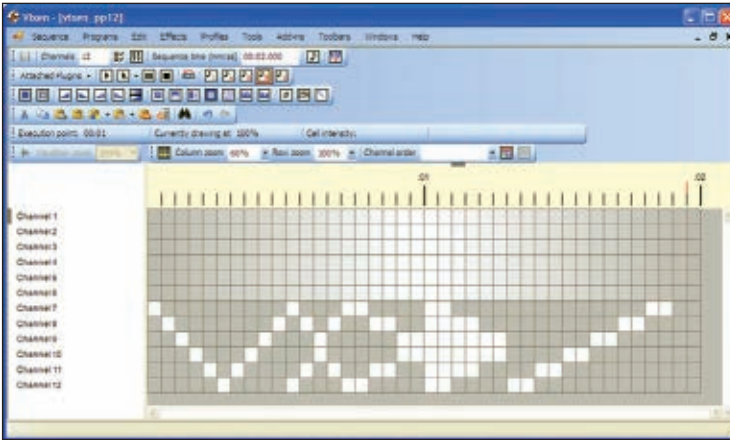


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■ FIGURE 6. PPM input circuit.

Vixen supports a lot of interesting protocols and with the flexibility of Spin, it will be worth investigating more of them — but let's save that for another time, shall we? Since we could add two half-duplex ports to the Propeller Platform using the Gadget Gangster Prototyping board, it might be fun to create a traditional Propeller-based Renard device that handles the pass-through. Are you up to it? Of course you are, and I'll probably try it myself down the road.

For now, though, since this is my last column of the year, let me wish you and yours the very best for this

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holiday season and the coming new year. I am grateful to get to share my experiments in *Nuts & Volts* and sincerely appreciate Robin, Larry, and all the nice folks I interact with at T & L Publications, Inc.

Of course, I must also thank my friends at Parallax (that started for me with a BASIC Stamp 1 some 16 years ago), my colleague, John Barrowman, and, finally, my wonderfully supportive friends and family. May God bless you all.

Until next time, light up your life and keep spinning and winning with the Propeller! **NV**

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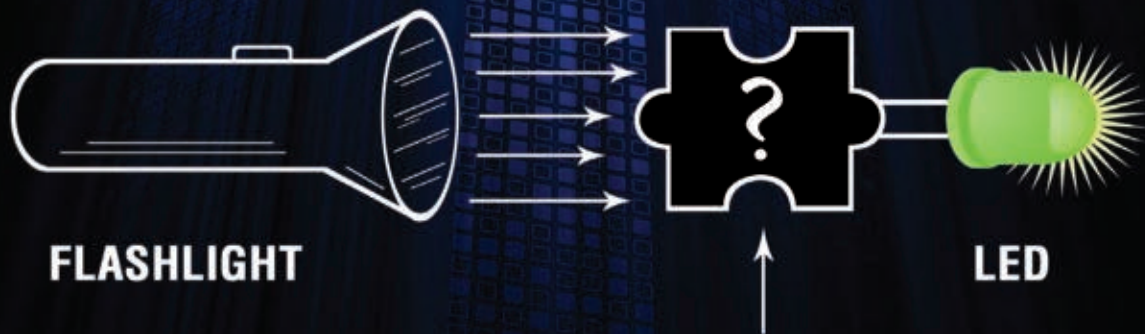
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Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in non-volatile memory for future use!

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. (Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM30B	Digital FM Stereo Transmitter Kit, 0-25mW, Black	\$199.95
FM35BWT	Digital FM Stereo Transmitter, Assembled, 0-1W, Black (Export ONLY)	\$299.95

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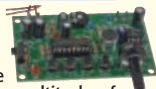


Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition, a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Safe 9V battery operation.

ECG1C	Electrocardiogram Heart Monitor Kit With Case & Patches	\$44.95
ECG1WT	Electrocardiogram Heart Monitor, Factory Assembled & Tested	\$89.95
ECGP10	Electrocardiogram Re-Usable Probe Patches, 10-Pack	\$7.95

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This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even add vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.



MK171	Voice Changer Kit	\$14.95
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## Laser Trip Sensor Alarm

True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1	Laser Trip Sensor Alarm Kit	\$29.95
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## Steam Engine & Whistle

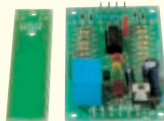
Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.



MK134	Steam Engine & Whistle Kit	\$11.95
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## Liquid Level Controller

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K2639	Liquid Level Controller Kit	\$23.95
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LED animated motion makes it come alive. Runs on standard 9V battery or 9-12VDC external power supply. Dazzle your friends this great display!

MK116	LED Animated Santa Kit	\$16.95
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### LED Christmas Tree

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MK117	LED Christmas Tree Kit	\$18.95
-------	------------------------	---------

### LED Animated Holiday Bell

This PC board holiday bell is animated to simulate a bell swinging back and forth! 84 bright colored LEDs will dazzle you with holiday cheer! Includes an on/off switch. Runs on 9V.



MK122	LED Animated Bell Kit	\$16.95
-------	-----------------------	---------

### 3D LED Christmas Tree

Not your average LED display! 4 branch sections give this tree a true 3D look! 16 red LEDs light it up with yellow LED's for you to customize your tree! The base of the tree is actually the 9V battery acting as a self supporting base! Now that's pretty neat!



MK130	3D LED Christmas Tree Kit	\$7.95
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### SMT LED Christmas Tree

Build this subminiature Christmas tree and learn SMT at the same time. Small enough to wear as a badge or pendant! Extra SMT parts are included so you can't go wrong! Runs on Li-Ion cell.



MK142	SMT LED Christmas Tree Kit	\$10.95
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### SMT LED Smiley Face

This is a great attention grabber and also teaches you the basics of SMT construction! Perfect to wear through the holiday season or to hang on your tree as an attention getting ornament! Extra parts included! Runs on Li-Ion cell.



MK141	SMT LED Smiley Kit Kit	\$9.95
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### LED Traffic Signal

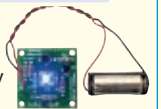
Not exactly a holiday theme, a real attention getter for this time of the season! Impress your friends with this neat 4-way traffic signal! Operates just like a standard signal, and features adjustable delay. Red, yellow, and green LEDs are used just like the real thing! Runs on 9V battery.



MK131	LED Traffic Signal Kit	\$7.95
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### LED Switcher Blinky

Wait, an LED that runs on 3VDC running on 1.5VDC? Learn power supply switching and end up with a super bright Telux LED blinking at 140 kHz! Great to light up your ornaments! Runs on a single standard AA battery (not included).



LSW1	LED Switcher Blinky Kit	\$14.95
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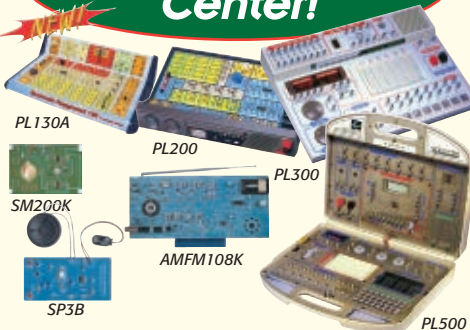
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# Q&A

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Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Seven-Segment LED Help
- ✓ LED Flasher and Beeper
- ✓ Attic Fan Control

### ■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: [Q&A@nutsvolts.com](mailto:Q&A@nutsvolts.com)

## ATTIC FAN CONTROL

**Q** I have two separate attic exhaust fans (they run on 110 volts AC). Each fan has its own thermostat. The thermostats are very inaccurate and difficult to synchronize. I would like to set up a single, more accurate thermostat that would control both fans so that they will turn on and off at the same time. I have thought of using a furnace thermostat and some sort of relay, but I am not sure how to set this up. Can you make any suggestions?

— Guy Fischetti

**A** Home thermostats are designed for 24 VAC and low current, so you will need a relay (see **Figure 1**).

In the parts list, the transformer has quick-connect terminals (faston), but you can find similar transformers at the local hardware store. I would not buy the universal 240/120 VAC type because the wire is smaller and less reliable. The thermostat will also be available at the hardware store; the round Honeywell type is what I have in mind. The Panasonic relay can be mounted with two screws on any flat surface and the contacts are quick-connect terminals.

## MICRO HELP

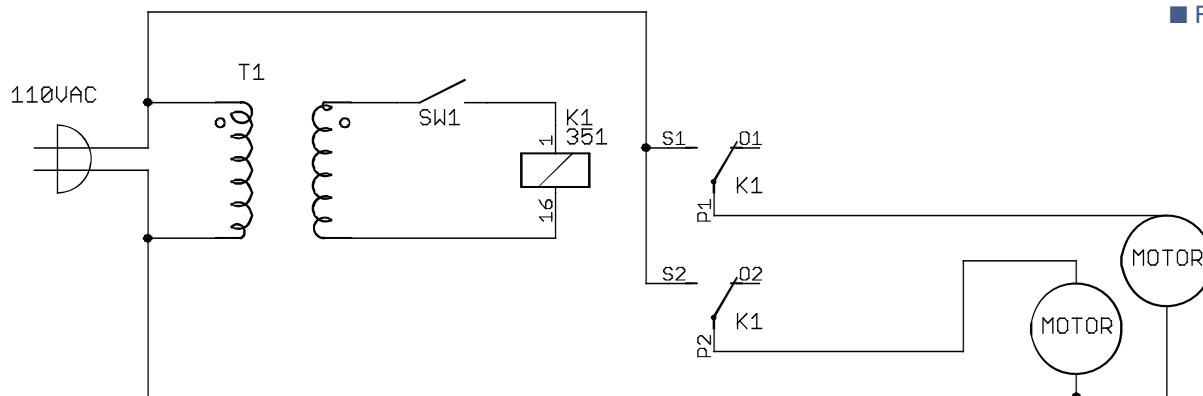
**Q** I have a piece of equipment that uses a Motorola 68HC711E9 micro which has some programming burned in. I want to copy out the program and purchase a few of these (getting almost

extinct) ICs and burn a few spares. I've looked at some stuff on the market but I'd like some help if you don't mind; I want to keep it simple and cheap but accomplish the task. Thank you in advance for some advice/help.

— Michael Shelton

**A** I am an analog engineer; I would expect you to know more about this than me. However, I looked up the datasheet and see that there is no provision for copy protection, so it should be easy. I found the EVB Plus2 development board for \$189 that should do the job. If you can program an EPROM, the info at [www.dataman.com/WebPages/Support/S4/SupportS4ProgrammingThe68HC711.aspx](http://www.dataman.com/WebPages/Support/S4/SupportS4ProgrammingThe68HC711.aspx) should be helpful.

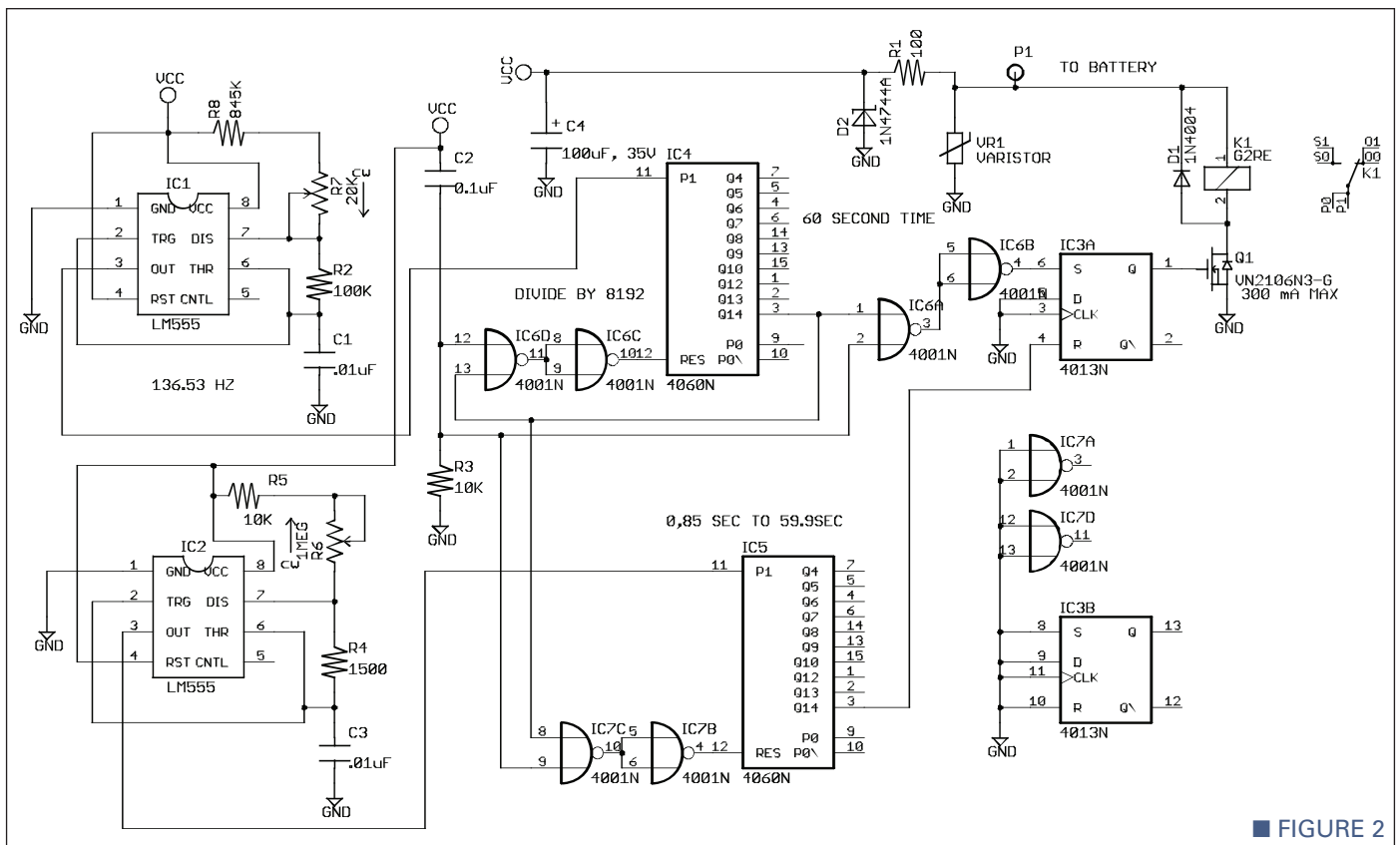
Feedback from Michael: I did



■ FIGURE 1

PART	DESCRIPTION	MOUSER PART NUMBER
T1	110/24V TRANSFORMER, 30VA	553-F6-24
SW1	HOME THERMOSTAT, HOME DEPOT,	HONEYWELL CT31A
K1	24VAC RELAY, 10A @ 120VAC	769-HL2-HTM-AC24V-F





■ FIGURE 2

some searching before I got your reply. After some exchanged emails, etc., I bought one just for the 68 series 52 pin from Tech-Arts in Canada ([www.technologicalarts.ca](http://www.technologicalarts.ca)) for \$32. With the software link to download and furnish a 12V ext supply to program, he said it would more than meet my needs.

## TIMER PROJECT

**Q** I need a variable ratio timer set-up so that as you increase the relay ON time, you automatically reduce the OFF time. The cycle should repeat until the timer is turned off. It needs to be set up using one potentiometer to adjust the time periods. The complete cycle is about one minute and should operate from a 12-volt DC automobile battery.

I have been successful in setting up two timers for this purpose, but it requires adjusting two potentiometers.

As with a lot of your readers, the first place I go when a new issue of *Nuts & Volts* comes in is "Q & A,"

trying to solve problems of others and to learn more. I enjoy your magazine; lots of it is way over my head, but slowly I am learning. I am only 70, so I still have some time left to experiment and learn.

— Morris Sandlin

**A** I first thought of using the SN74LS292 programmable frequency divider until I discovered that it costs

\$14+ each. It would have been neat because of digital precision which would eliminate the possibility of accidentally making the pulse width greater than the period (which results in a narrow pulse instead of a wide one). I decided to go with a less expensive circuit (see **Figure 2**).

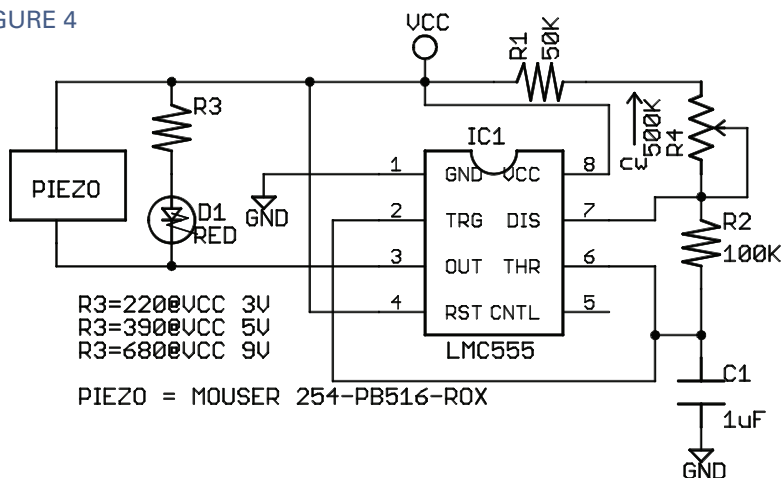
I used the CD4060B frequency divider which has a provision for a built-in R-C oscillator but it won't

## TIMER PROJECT PARTS LIST

■ FIGURE 3

<u>PART</u>	<u>DESCRIPTION</u>	<u>MOUSER PART #</u>
RESISTORS	METAL FILM, 1/4W, 1%, AXIAL	271-VALUE-RC
R6	1 MEG POT, 1/8W	31VC601-F
R7	TRIMPOT, 20K, 1/8W	81-PV37W203C01B00
C1, C3	.01 $\mu$ F, 100V, 5%	505-MKP20.01/100/5
C2	.1 $\mu$ F, 100V, 5%	505-MKP20.1/100/5
C4	100 $\mu$ F, 35V, ALUMINIUM	140-XAL35V100-RC
IC1, IC2	555 TIMER, 8-PIN DIP	512-LM55CN
IC3	DUAL D FLIP-FLOP, CD4013	595-CD4013BE
IC4, IC5	14 STAGE COUNTER, CD4060	595-CD4060BE
IC6, IC7	QUAD 2 INPUT NOR, CD4001	595-CD4001BE
VR1	22V, 43V@5A	650-ROV10-220L-S
D1	400V, 1A, 1N4004	512-1N4004
D2	ZENER, 15V, 1W, DO-41	78-1N4744A
Q1	NFET, 60V, 300 mA	512-BS170
K1	AUTOMOTIVE RELAY, 12V	653-G8JN1C7TMFRDC12

■ FIGURE 4



work over the wide range that I need. That is why the 555 oscillators were used. With 14 stages, the 4,060 divides by 16,384 but I am only using half the period. The output is initially low and goes high after 8,192 clock pulses. When the output goes high, it feeds back and resets itself to start another time period. There is a power-on reset through C2 which resets all the flip-flops. The parts list is **Figure 3**.

The variable time (R6) is less than one second to almost 60 seconds. If the variable time exceeds the fixed time, the pulse width is the difference which will be very small; you may want to tweak R4 and R5 but don't make R5 less than 1K because when R6 is zero, the discharge transistor has to pull current through R5. The only reason for R2 and R4 is to make the 555 output pulse wide enough that you can see it on an oscilloscope.

The components VR1, R1, D2, and C4 are to protect the circuit from the transients of the automotive system which can reach 60 volts or more.

## SEVEN-SEGMENT LED HELP

**Q** I have a whole box of seven-segment LEDs of assorted sizes. Some are multiple character; some have decimal points. They go from 14 pins up to many pins. Some are common anode, some common cathode. I haven't been able to find the pinouts anywhere on the Internet for LEDs in general. I think it would be good if you could tell us where to look to get that info. Or better still, how to test to find out where the segments are for each character and whether it's a CA or CC.

I tried this: Set bench power supply to 1.5 VDC. Connect one probe to any pin. Run the other probe along the remaining pins until something lights. If not, swap the probes and do it again. One of the two pins must be the common. Then, determine which is which. Then, identify the segments pin by pin. For some reason, this doesn't always work. There must be a better way as many of these are made in China or some place like that and there is no datasheet available or it's in a foreign

language. Help bail out us "duffers."

— C. P. Furney, Jr.

**A** A Mouser or Digi-Key catalog may be helpful. Find a similar device and download the datasheet, then check if the pinout of your device is the same. Otherwise, I don't know of any method better than what you have done. However, I would use a five-volt supply with 1K in series to limit the current; 1.5 volts would not light up some colored LEDs.

## LED FLASHER AND BEEPER

**Q** I'd like to modify a 9 VDC LED flasher diagram by adding a mini-beeper to 'beep' in tandem with the LED; also, I'd like to add a 5K (or other value) variable resistor to select the speed from 'fast' to 'slow' to beep and flash in tandem.

Lastly, I would like a second schematic that would do everything just as above but be powered from a 3 VDC source. Thus, incorporate a CMOS 555 timer instead! Can you please help with these two schematics?

— Michael Williams

**A** Only one schematic is needed because the LMC555 will operate from 3V to 12V. In **Figure 4**, R5 varies the speed from fast to slow and R1 sets the maximum speed. Changing speed also changes the duty cycle so you don't want to go too fast because the beep and blink will get very short. You could fix R3 at 390 ohms, and the brightness of the LED will vary with supply voltage. You could use the SBZ-204 buzzer; I didn't because I did not know where you found it. **NV**

## MAILBAG

Dear Russell: Re: Inexpensive Drafting Software, April '10, Page 26.

I have an old OrCad package that works wonderfully for electronic schematics, but for a general-purpose,

all around drafting package that can do mechanical or architectural drawings, electrical schematics, and flowcharts, I suggest TurboCad. Version 16 is available from Internet sites for under \$80 plus shipping and tax (if any). It has a huge library of shapes for all purposes and it

comes with a tutorial.

— Peter A. Goodwin

I have used AutoCAD LT with a Via Schematic plug-in but it is cost-prohibitive — about \$2,000 a few years ago. However, I think I have an excellent choice for the flow-charting



**Mailbag Continued ...**

software. I use Raptor at college (ITT-Technical Institute) and it is available at <http://raptor.martincarlisle.com>. Best of all, it's free and really small.

— Joseph Fulton

Dear Russell: Re: Soldering Iron Timer, March '10, Page 28.

While reading the question, I realized that I had already solved the problem. Two years ago, I had purchased a 24 hour single setting timer for about \$4. (Some single set timers were twice as expensive.) The timer can turn the outlet on and off once in 24 hours in 15 minute increments. I changed the internal wiring so that the motor is also cut off at 0 hours. I glued a paper scale marked with 0 to 23 hours on the face. The red tab is set at zero and the green can be moved to have the outlet active for up to 23.5 hours. Both the outlet and motor are turned off when the timer reaches 0.

I have been using the timer for recharging batteries. I used to forget to turn off the charger, but not any more.

— Anonymous

Dear Russell: Re: Mystery Component, July '10, Page 25.

I believe the mystery component Jon Carter is referring to is a thermal fuse. If it is a 1/4" x 1" cylindrical metal part with one pointy end, that is what it is. We have run into these many times embedded in transformers. One brand is MICROTEMP, made by THERM-O-DISC. If there is a dead short, these act like a fuse and open immediately. If they get over their rated temperature, they act like a thermostat, but do NOT recover.

— Warren Cook

*Response: Thanks for the feedback, Warren.*

In your column, a person asked about a mystery component in a microwave oven. The component inside the transformer is a thermal fuse. It blows under two conditions: over current and over temperature. If this fuse is blown, the transformer is considered bad. I used to repair

microwave ovens and the only way to get this transformer is to buy a new timer unit. Putting any part in there will compromise the UL safety.

— Randy Carter

*Response: Thanks for the feedback, Randy. I would forward your comments to Jon Carter if I could find the original email!*

Dear Russell: Re: Power Supply, July '10, Page 24.

According to the Hammond transformer website — [www.hammondmfg.com/pdf/5c007.pdf](http://www.hammondmfg.com/pdf/5c007.pdf) — IDC output = .62 x IAC for a FWB with cap input power supply. That means that their 3.8 amp transformer will only produce an output of 2.3 amps DC when used in your circuit.

— Mike Eck

*Response: Thanks for the feedback, Mike. You are right, that transformer will overheat if loaded to three amps. Your comment brought to my mind the question: How much inductance — in series with the rectifiers — will produce a continuous current such that full VA rating applies? Trial and error simulation indicates that 5 mH will do it but I can't find an inductor rated 5 mH at three amps. One could connect seven 680 uH inductors in*

*series (Mouser PN 542-2322-V-RC) if you want to do it.*

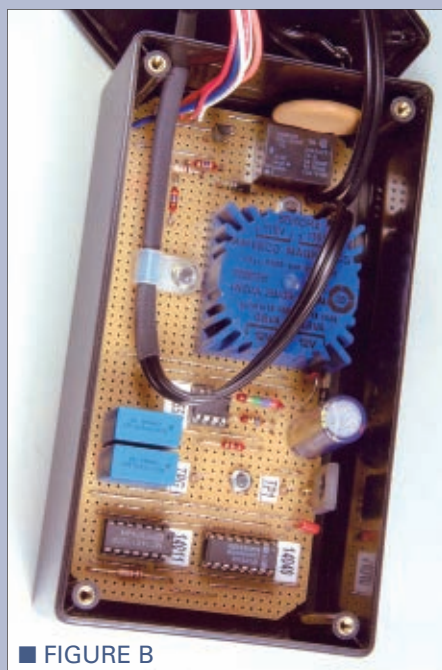
Dear Russell: Timer, July '10, Page 25.

Thank you for your suggestion for building a two-hour timer. I am enclosing some pictures which I took of the finished units (**Figures A and B**); two were made. Your circuit was used almost exactly as you presented it except that I omitted the trimpot. I used a larger series resistor (560K) paralleled with one determined using a decade box.

The units as originally built controlled the AC line using a 4015L2 thyristor/MOC3020 solid-state relay combination. However, I found that the power was not being turned off with the very small load of a small "wall-wart." The voltage dropped to only 65 volts! Only then did I think to check the specs of the 4015L2; the minimum current is listed at 0.8A! One of those obscure facts you learn with experience. As you can see in the pictures, a relay was substituted.

Since only two were required, the circuit was assembled on a Vero board rather than an etched one. The timing capacitor was metallized polyester rather than an electrolytic for long-term reliability. I thought that you might like to see how one of your "babies" turned out. Once again, thanks.

■ FIGURE A



■ FIGURE B

## Mailbag Continued ...

— Bill Woods

*Response: Thanks for the feedback, Bill; you did a great job.*

Dear Russell: Re: Video Switch Code, August '10, Page 24.

It seems to me that the code as printed in the magazine will not work. Since you say you breadboarded it and it works, then I presume there is a misprint or an older nonworking version was printed. Basically the code around the label HOLD: will not work as desired.

It is coded (as printed) as a single if statement that will update the outputs (GPIO = Y) if the button is not pushed, but will then continue past the endif statement to the next J and continue to cycle through all four inputs; it will then fall through the next J into the cycle LOOP:. This code will not stop on one video input. I believe the code should be.

```
GPIO = Y    \ output the
              \ calculated pattern
HOLD:       IF GPIO.3 Then HOLD
              \ stay here till button is
              \ pushed.
```

Judging from your HOLD label, I assume you wanted the code to hold here till it sees a button push. Probably something got lost in the printing. Also, why are some words in **BOLD** and later in the LOOP code none are bold? I also feel that your handling of the button pushing could be better. There is, of course, the problem of bounce which I will ignore for now. These little machines are fast and basically will be in either pause mode or a button checking loop like the above "if statement" all the time. The way your loop code is written (with the 1/2 second pauses in the timing loops then checking for the button) means that you may have to hold the button down for 1/2 second or slightly longer to even be detected. If one should push the button while

in the 1/2 second pause and let go of the button before the pause is over, then the button push will never be detected. If you hold it too long, you may go past the one second pause you use to give "time to get your finger off the button." I would recommend a smaller time interval in the pause used in the button checking timing loops; maybe a tenth of a second. Also, rather than pause an arbitrary one second after detecting the push, you could actually look for the button release ... code similar to the HOLD code above looping on itself till a button is released would work nicely no matter how long someone pushed the buttons. I presume your system is very touchy as to how long buttons must be pushed and held down till released. It looks to me like the pause 1000 code for button release came out as a quick solution to problems during your debugging stages. Since your application uses a momentary push to cycle through software options, a mechanism to

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## QUESTIONS & ANSWERS

### Mailbag Continued ...

detect a complete cycle from push to release could be used before entering the code to be acted upon.

Contact bounce, of course, brings in its own little problems that can be solved either with hardware or in software. For those not familiar with contact bounce, it is the mechanical "bounce" of the metal contacts as they first hit until they settle down in a continuous closed contact. Computers are fast enough to see this as several closing and opening cycles of the switch. If not compensated for, software will be all over the place when one intention is a single event. In software, one would detect the first contact closure, wait a short time for bounce to stop, then if desired, wait for the first nonclosure, and again a short debounce delay, and then continue on with code for a momentary pushed button as desired in this project. Other projects may need to operate only as long as the button is closed. Hope this helps someone out there.

Sorry if this got a little long, but there are issues here in real time code that programmers should be aware of if they want their systems to behave as they intended and to interact with humans in a user friendly manner.

— Evan Wasserman

*Thanks very much for taking the time to analyze the code. Looking at it now, I don't understand why it worked (just as I don't understand why it doesn't work sometimes). Your suggestion for the HOLD loop is a good one. I should have thought of that. I am aware of the contact bounce problem but figured that the PAUSE 1000 would take care of it. The code could have been better, as you pointed out, but I am still learning. The program that I use (Microcode Studio) automatically puts reserved words in bold.*

Dear Russell: Re: Irrigation Timer August '10, Page 22.

I always read your column with great interest. I was wondering whether the circuit needs to be protected from indirect surges. My sprinkler timer (the Champion PR-90) has protection (a MOV) at each terminal block. A ribbon cable runs from each terminal block to the PCB in the controller (a surge will hit the MOV before it hits the solid-state components). There could also be some additional protection on the PCB. Also, the PR-90 sprinkler timer allows the times to be digitally adjusted from 10% to 300% to change watering times depending upon the temperature, humidity, etc. The PR-90 sprinkler timer allows each zone time to be adjusted from 10 seconds to one minute in five second increments; one minute to one hour in one minute increments; and one hour to 12 hours in 10 minute increments which seems adequate to fulfill the needs for the drip irrigation system without any additional circuitry.

— Alan Sciacca

*Response: Thanks for the info, Alan. Readers may be interested to know a commercial unit is available.*



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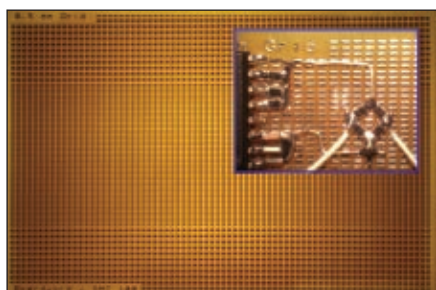
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considered “perf board for surface-mount.”

The system consists of a simple grid of pads that is designed to accommodate all pin pitches available on various parts by having the user shift the device around at mounting time to find the best fit, then tacking the part down. This is followed by hand-wiring the interconnects between parts with bare fine wire. The result is a small, tight neat package, utilizing SMT and through-hole parts if desired.

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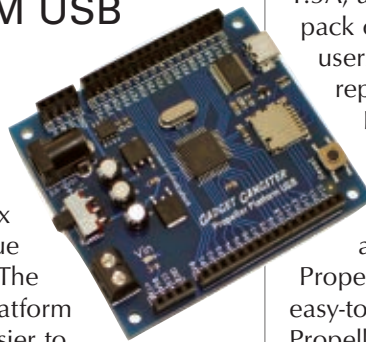
of the board for the best fit of components. The SMT-100 is a basic board, 2 x 3 inches, featuring a universal grid on which to mount parts; it's intended for general prototyping of small to medium sized circuits. The SMT-200 features a set of large pads on the back of the board that can be used as a plane for convenient electrical connection (via holes through the board) or for heatsinking and mounting larger power components. The SMT-300 addresses the SMT and through-hole hybrid designs, combining 100 mil spaced through-holes which border two SMT universal grid areas.

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Additionally, this board can be used for building custom adapter boards from surface-mount parts for mating to solderless breadboard applications. The SMT-400 is a small mini board (just under one inch square) allowing for small "fix" or daughterboards to be constructed.

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Also handy are its power capabilities; 5V and 3.3V ultra low dropout voltage regulators run up to 1.5A, and you can connect a battery pack or wall adapter. Advanced users will appreciate the replaceable crystal and expanded EEPROM for overclocking and data storage. The Propeller Platform USB is designed and assembled in the USA and is open source. The Propeller Platform USB is a flexible, easy-to-use development tool for the Propeller. Propeller tutorials are available at the website listed here.

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The 3D LED

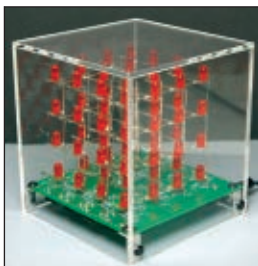
cube from Images Scientific is composed of 64 mono-chromatic LEDs arranged in a 4 x 4 x 4 matrix.

LED lights create animated patterns that blink, morph, and change. Four pushbuttons on the bottom of the LED cube allow the user to select the mode, and scroll through the 3D animations available.

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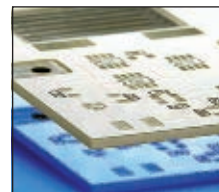
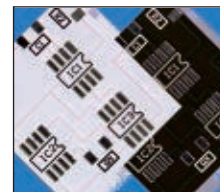
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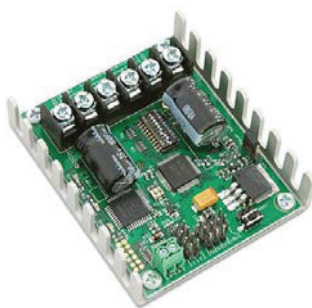
business with, Sunstone Circuits has responded to feedback from the engineering community by not only improving the feature set of PCB123, but also configuring the software into a more user friendly and intuitive resource. As a result, design engineers now have access to a free industrial-grade CAD tool that is setting a new standard in the industry. Some of the key features in the release of PCB123 v4 include:

- 500,000 New Parts: Improved search functionality with complete access to parts libraries (powered by Accelerated Design).
- Datasheet Availability: Research in 'real time;' parts availability from Digi-Key.
- Automated BOM (Bill of Materials): For ease in purchasing and assembly.
- New Data Importer: Gain efficiency by importing DXF files from mechanical CAD tools, removing tedious pain-points that slow down the design process.
- Buildable Designs: Sunstone's

DRC/DFM rules are integrated into the software to deliver more effective feedback and fewer design spins.

PCB CAD tools have traditionally concentrated on the hard engineering issues, like impedance calculations and trace routing tools. What has been overlooked is the ability to provide design engineers with information regarding the economic or supply-chain constraints that affect design times. With PCB123 v4, Sunstone brings the first fully-realized set of tools that allows its users to design with full knowledge of the budgetary and scheduling impacts of their design decisions, as well as the hard engineering information. Sunstone realizes that their users are held accountable for financial and budgetary constraints and that the tool they use should provide them that information.

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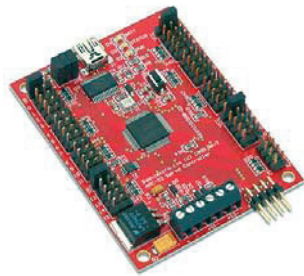
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# PIEZOELECTRIC FILM SPEAKER

By John Iovine

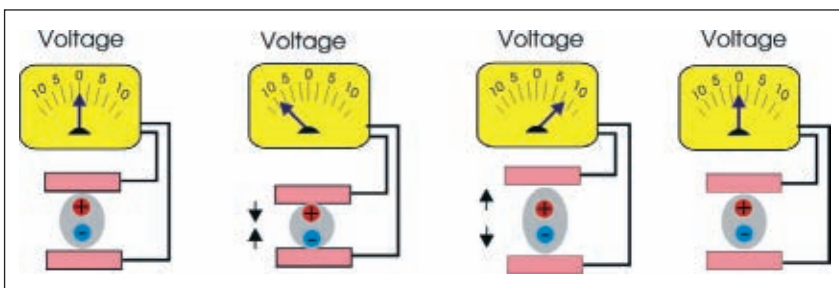
The word piezo is derived from the Greek word piezein, meaning to press tight or squeeze. Add the second term electric and you've got squeezed electricity.

Piezoelectric materials develop a momentary electric potential (voltage) when the material is placed under a mechanical strain. Inversely, piezoelectric materials will strain internally or change shape dimensionally (slightly) when placed under a suitable electrical field. (See Figure 1.)

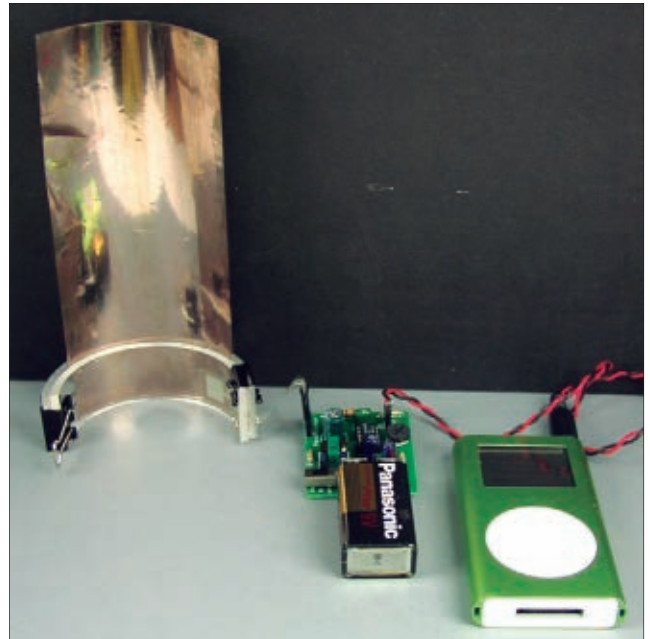
Naturally occurring piezoelectric materials are crystals. The piezoelectric effect was discovered by Pierre and Jacques Curie. In 1880, the Curie brothers published a paper on the piezoelectric phenomena and crystallographic structure of tourmaline, quartz, topaz, cane sugar, and Rochelle salt.

Since piezoelectric materials only develop momentary electrical potentials, in order for the electric potential generated to power an electrical device, the mechanical strain must oscillate to provide continual power to the device.

Figure 2 illustrates what the electrical response of a finger tap on piezoelectric film would look like on an oscilloscope. The initial pulse rapidly decays while oscillating.



■ Completed circuit board connected to audio source and piezoelectric film speaker.



## Piezoelectric Film

In this article, we will experiment with a unique piezoelectric material: piezoelectric film. Piezoelectric film is made from polyvinylidene fluoride (PVDF) which is a non-reactive thermoplastic. The piezoelectric effect in PVDF material was first observed in 1969 by Kawai.

To make PVDF piezoelectric, the material must become anisotropic meaning the molecular structure of the plastic compound must be aligned to create a piezoelectric effect.

This is achieved using two processes during manufacturing. The heated PVDF material is extruded and stretched in the length direction into paper thin material. This stretching causes some alignment of the internal plastic dipoles. To enhance the alignment of the dipoles, a high voltage "poling" voltage is applied to the surfaces of the plastic sheet material. This aligns most of the dipoles in the thickness direction that is perpendicular to the surfaces (see Figure 3).

The surfaces of the stretched and poled PVDF sheet material is then metalized with thin, electrically conductive nickel copper

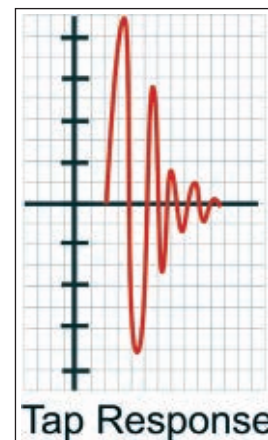
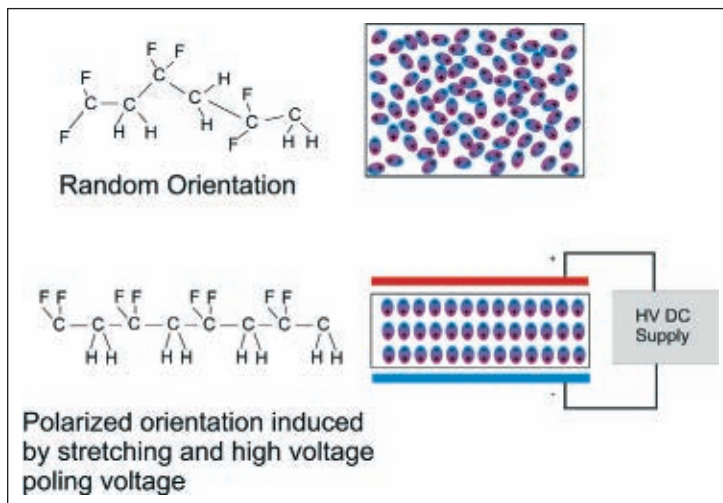
■ FIGURE 1. Electrical response of piezoelectric film to pressure.



## ■ FIGURE 2. Electrical response of piezoelectric film shown on an oscilloscope.

alloy on both sides to provide electrical contact.

To use piezo film, one makes an electrical connection to the electrically conductive coating on each side of the PVDF material. If one needs to attach electrical connections to raw piezo film, this is accomplished using either copper tape or a conductive epoxy. Soldering directly to the film is not possible because the heat would destroy the underlying plastic PVDF material. The piezo film speaker has a two-pin .100" header connection that we can easily use to connect to our circuit.



■ FIGURE 3 Dipole molecules in random arrangement and aligned arrangement after stretching and poling voltage.

## Pyroelectric

PVDF is also pyroelectric, meaning that it produces an electrical charge in response to a change in temperature. The material is sensitive to infrared energy between 7-20 um. This response allows it to be used for heat detection of the human body. Piezoelectric film sensors are used behind the fresnel lens in motion sensors where they can detect a human body at 50 feet.

## Ultrasonic Transducer

Piezoelectric film was used as an ultrasonic transducer for range finding in a few old Polaroid sonar cameras like the One-Step and SX-70. The sensor performed a dual function of first sending out an ultrasonic burst, and then acted as a receiver to catch the reflecting echo. The time lapse between the transmission and receiving the echo provided the range to the subject for the camera to focus. These sensors, as well as supporting electronics, are still available from Senscomp.

## Piezoelectric Film Properties

Piezoelectric film has an extremely high output voltage, about 10 times greater than piezoelectric ceramic materials. Since the material is a thin, lightweight flexible film, it can be glued on to shaped designs (one may use a variety of commercial glues). The material has a high

mechanical strength and is impact resistant. Other attributes include:

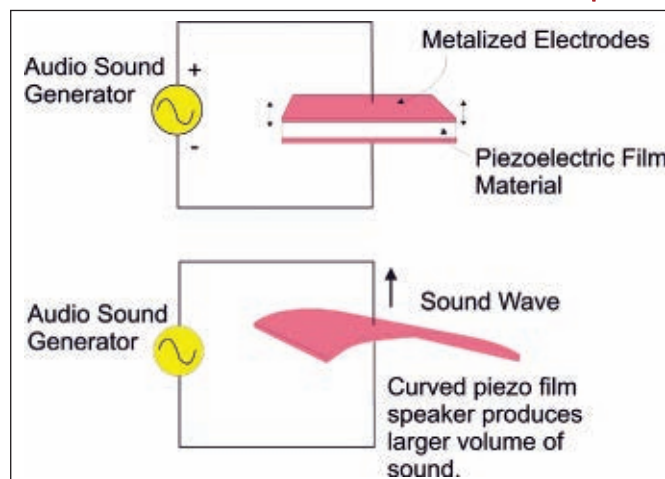
- Wide frequency range (.001 Hz -  $10^9$  Hz).
- Low acoustical impedance (close to water and human tissue; efficient for sonar and imaging).
- High dielectric strength.
- Good mechanical strength.
- Moisture resistant, inert to many chemicals.

One disadvantage to piezo film is that it is a weak electromechanical transmitter when compared to piezoelectric ceramics.

## Piezoelectric Film Speaker

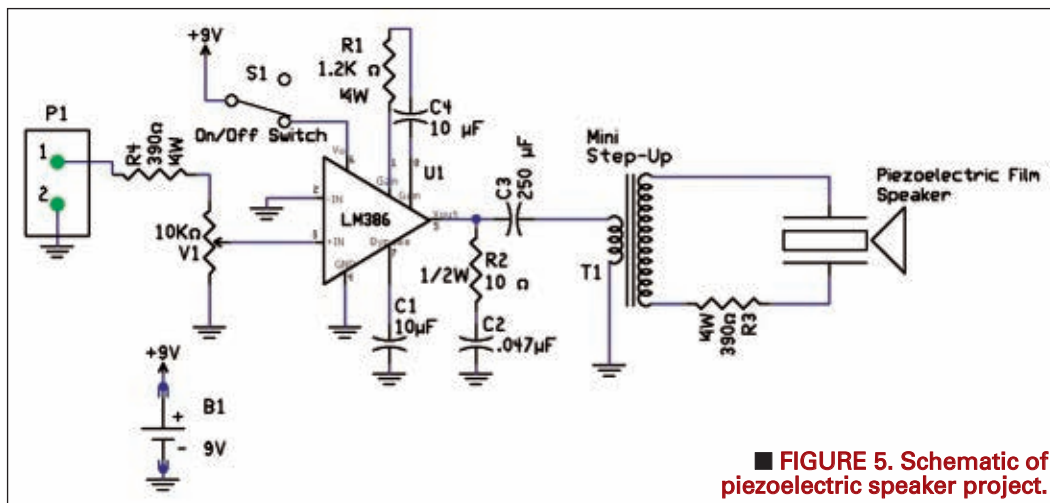
When an electric field is applied to a piezoelectric film, it deforms (see **Figure 4**). The film is able to compress and expand across its thickness under the influence of an electric field. It is this property that allows it to perform as a flat film speaker. For efficiency, a large piece of piezo material is used. The piezoelectric film

■ FIGURE 4. Audio signal impact on piezoelectric film speaker.



## PARTS LIST

- Piezoelectric Film Speaker
- Printed Circuit Board
- Eight-pin DIP Socket
- LM386 Audio AMP IC
- Slide Switch
- 9V Battery Terminals
- 10K Potentiometer PC Mount
- 390 ohm 1/4 watt Resistor
- 1.2K ohm 1/4 watt Resistor
- 10 ohm 1/2 watt Resistor
- (2) 10  $\mu$ F Capacitors
- .047  $\mu$ F Capacitor
- 250  $\mu$ F Capacitor
- (2) Two-pin female sockets
- Mini Step-up Transformer



■ **FIGURE 5. Schematic of piezoelectric speaker project.**

speaker measures three inches by six inches.

While the material does change dimensionally across its length, it is to a lesser degree as the dipoles are mostly aligned perpendicular to its thickness.

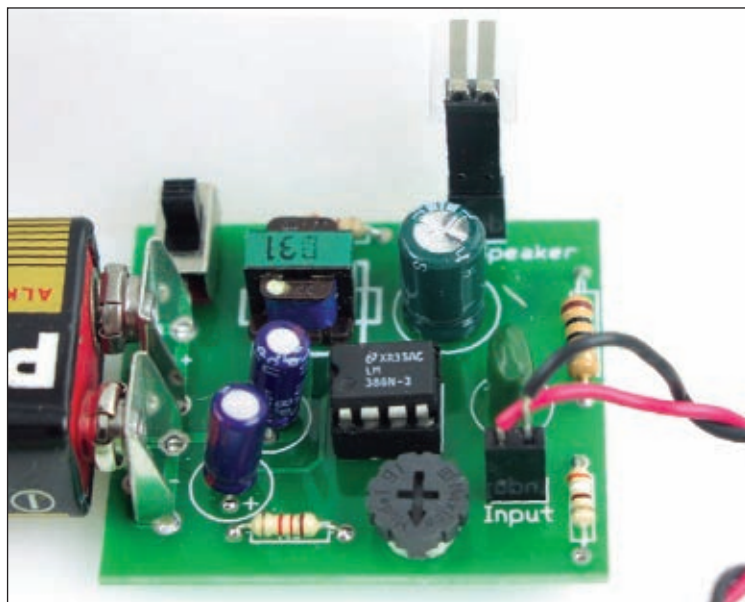
To use this material as a speaker, it is necessary to provide a high voltage audio signal. This is accomplished by feeding a standard audio signal through a step-up transformer.

Referring to the schematic in **Figure 5**, an electrical audio signal from a radio or iPod is applied to the input header P1. The signal feeds through a voltage divider network composed of resistor R4 and potentiometer V1. The signal from V1 feeds into the LM386 audio amplifier IC. V1 acts as a volume control. The LM386 is set up in a standard configuration to produce a gain of 50X amplification.

The output of the audio amplifier is fed to the primary of a mini step-up transformer. The high voltage output from the transformer is fed to the piezoelectric film speaker.

**Figure 6** is a close-up of the circuit built on a PCB

■ **FIGURE 6. Photo of piezoelectric film speaker built on a PCB.**



supplied with the kit available in the *Nuts & Volts* webstore.

**Figure 7** shows the speaker and circuit ready to go. I used an iPod for the audio source for the circuit. (The iPod is NOT included in the kit.)

## Construction

Mount and solder the HV transformer making sure to line up the yellow dot on the transformer to the silkscreen dot on the

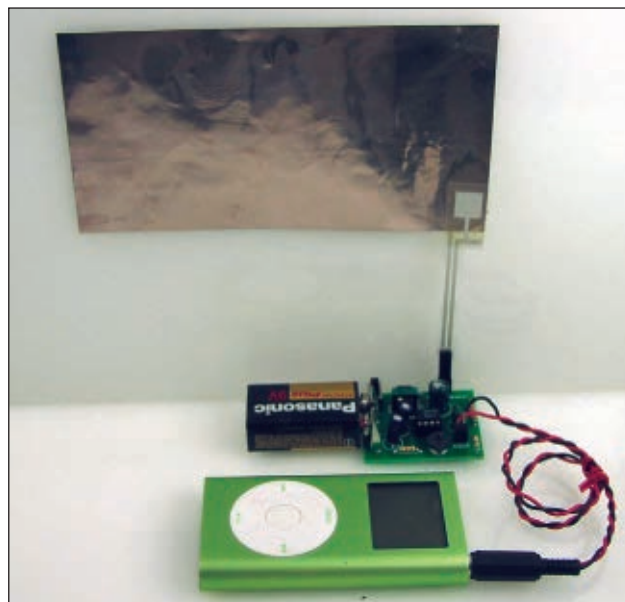
transformer outline. Mount and solder (V1) 10K potentiometer PC mount (R3 and R4) 390 ohm 1/4 watt resistor; R1 1.2K ohm 1/4 watt resistor; R2 10 ohm 1/2 watt resistor; C1 and C4, 10  $\mu$ F capacitors; C2, .047  $\mu$ F capacitor; and C3, a 200-250  $\mu$ F capacitor. Mount and solder slide switch S1. The input P1 and piezo speaker outputs are two-pin female sockets. Mount and solder into place. Plug the LM386 in the eight-pin socket. Orientate the indent on the IC to the indent on the silkscreen.

## Usage

Connect your audio source to the input header. Turn it on and set its volume range mid-point. Connect the piezoelectric film speaker to the output. Turn on the circuit and adjust the V1 volume control until you hear sound coming out of the speaker.

By curving the speaker, the sound volume increases. If

■ **FIGURE 7. All the components of the system: circuit, speaker, and audio source.**





you connect the piezo speaker leads to the input leads of an oscilloscope and tap on the speaker with your finger, you ought to get a trace very similar to **Figure 2**.

You could also see voltage change with the application of a temperature change. I do not recommend applying heat to see this voltage change. It is too easy to permanently damage the film. If you are adventurous, try applying heat from a bare incandescent lamp while observing the trace on a high impedance oscilloscope. **NV**

A complete kit to go with this article can be purchased online from the *Nuts & Volts* Webstore [www.nutsvolts.com](http://www.nutsvolts.com) or call our order desk at 800-783-4624.

## REFERENCES

Kawai, H., (1969). *Jpn. J. Appl. Phys*, 8, 975-976.

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# IS YOUR GARAGE DOOR OPEN?



By Ron Newton

**We live in a two-story house with two separate garages, each with two doors. One garage houses an electronics laboratory and the other a machine shop. We are not able to see them from the house without going outside. During the summer, I often leave the doors open for ventilation. Our neighbors (bless their hearts) call us and tell us our garage doors are open. Sometimes in the middle of the night I wake up and have to get up to see if I have left them open.**

**H**ard-wiring is always a problem, especially with an old house. With the new Linx transmitters and transceivers, this can be done wirelessly. The cost of the project is less than \$65 + boards. Pre-programmed chips and boards are available in the *Nuts & Volts* Webstore.

The primary design shown here was made for a single garage door. Installation is simple. Using Velcro tape, the transmitter is placed on the back of one of the panels of the door, and the receiver is in the bedroom. When the door goes up or down, the receiver indicates its position. There's no wiring of switches as it uses an internal tilt switch.

If you have more than one garage door, the transmitter can be hard-wired for up to three doors using magnetic switches; it will indicate each door's position. A single receiver receives and decodes three garage doors, and they don't have to be in the same location. The transmitter and the receiver use two AAA batteries which should last six months to a year. Both the transmitter and receiver have an audio indicator to let you know when the batteries need replacing.

The receiver also has a switch that can be activated to be an alarm if any of the doors are opened by a burglar. See **Figure 1**.

## Electronics

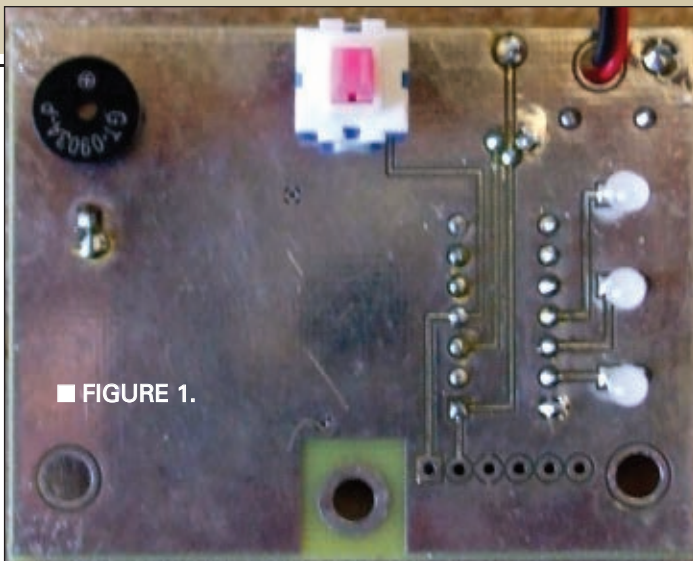
In both the transmitter and receiver are two ICs, a Linx transceiver, and Microchip PIC16F505 which directs the transceiver. A voltage detector is used to determine if the batteries are getting low.

The transmitter is put to sleep to save power. It draws 12 micro-amps when sleeping. The transmitter activates every 2.3 seconds by use of a watch dog timer (WDT). When the WDT times out, the unit checks the battery voltage. If the voltage drops below 2.4 volts, it beeps. The transducer resonates at 2.730 kHz. The micro proves a square wave at this frequency; the 10  $\mu$ F capacitor blocks DC but allows the AC to pass.

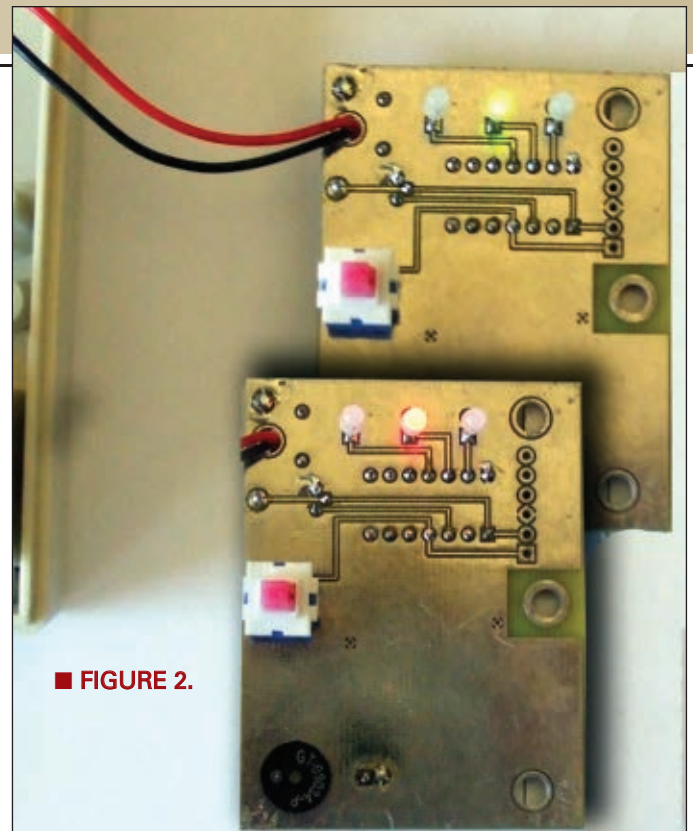
If the tilt switch or any of the magnetic switches activate, it transmits a code to the receiver. The code is 16 bits wide and the first three lower bits determine which door is open. This leaves 13 bits for scrambling  $2^{13} = 8,192$  combinations. The transmitter turns on the Linx transceiver and sends the codes. It transmits for about five seconds and goes back to sleep. The code combination flow sheet is located on the NV website.

The receiver basically has the same parts but uses three bi-colored LEDs to indicate door positions. See





■ FIGURE 1.



■ FIGURE 2.

**Figure 2.** It also wakes up every 2.3 seconds and looks for a valid transmit signal and code for 20 microseconds. If there is none, it goes back to sleep. It counts four 2.3 cycles and then flashes either green or red indicating the door positions. If it receives a signal from the transmitter, it changes its display and will flash the LEDs until the transmitter stops its transmission.

Both micros control the transceiver's power using the PDN line control. The T/R SEL pin differentiates between sent data and received data.

## Construction

### Boxes

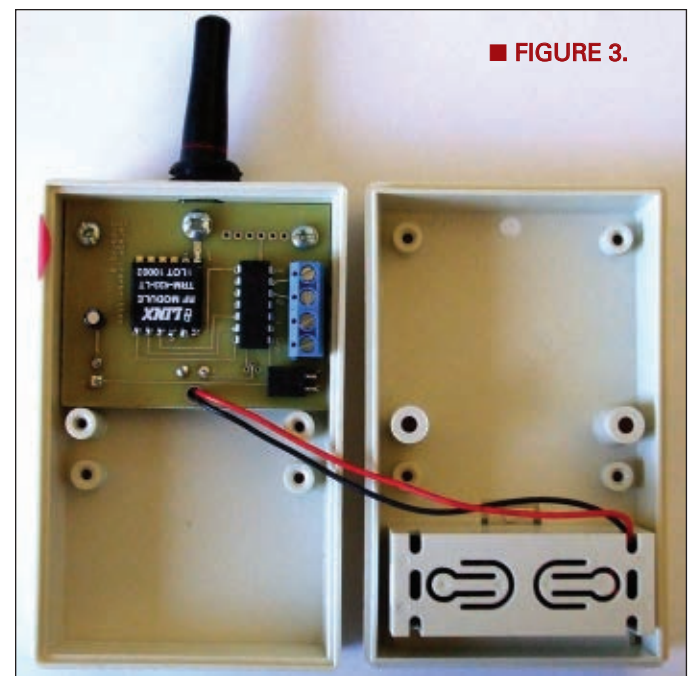
Go to the downloads link indicated here and download Garage. There are templates included in the attached files. Print and cut them out. With the two halves together, turn the box over and locate the battery holder area. Place the battery area towards you and turn the box face up. The board and antenna go on the far end as shown in **Figure 3**. (The box will not go together if the top half is reversed). Using a glue stick, glue the antenna template, front panel template, and side templates to the box. Using a drill press, drill the proper size holes as indicated on the templates. The receiver box is done the same way, however, there are no side holes; only the front panel and antenna. After the holes are drilled, use hot water to remove the templates and glue.

### Transmitter

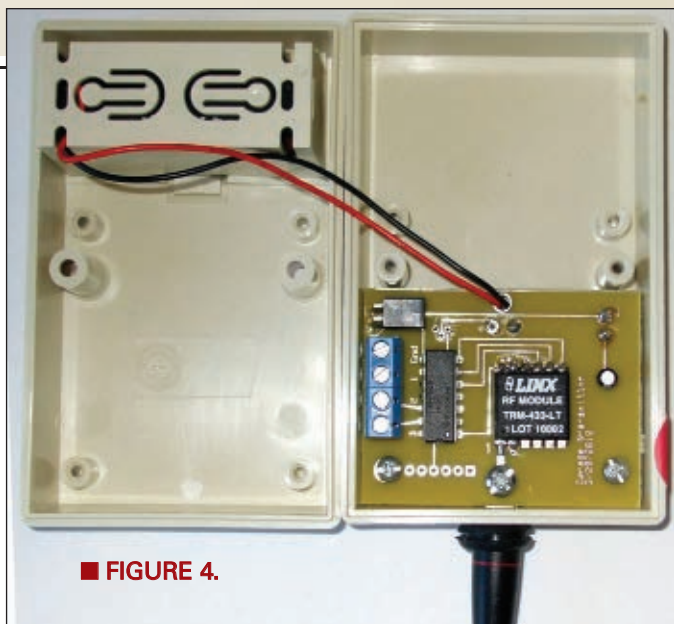
On the top of the board, mount the Linx module first, then the microprocessor, capacitor, terminals, and the voltage detector. The tilt switch is mounted on its side with its terminals toward the edge of the board. The transducer is mounted on the bottom of the board. Look at **Figure 4**. Note the polarities on the components which require them. Thread the wires from the battery holder through the slots of the battery compartment, through the antenna, and place it through its hole. Add the board over the antenna and secure with a screw. Use two self-tapping screws to secure the board to the box.

### Receiver

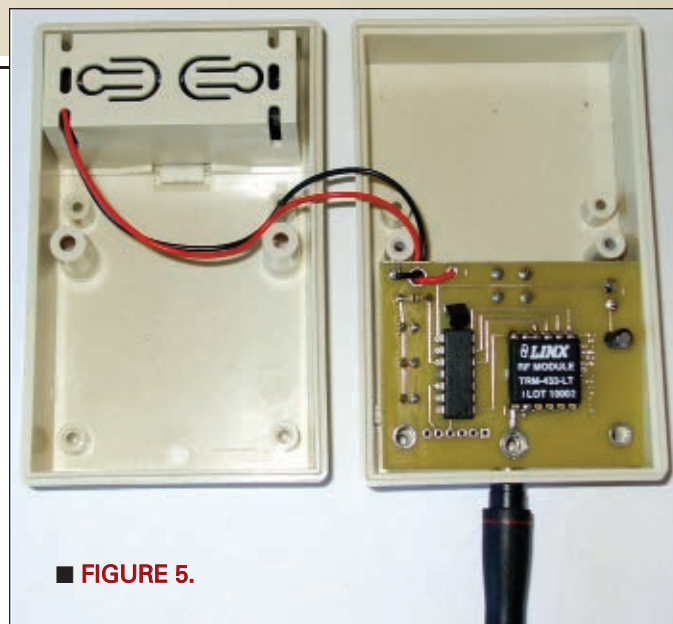
On the top of the board, mount the Linx module first, then the microprocessor, capacitor, resistor, and the voltage detector. Add the transducer, LEDs, and the switch on the bottom side. The best way to insure the correct length of the LEDs is to place them in the board, place the board in the box, seat them in their holes, and solder the leads. Take a look at **Figure 5**. As above, solder the battery holder wires and install the antenna.



■ FIGURE 3.



■ FIGURE 4.



■ FIGURE 5.

## Testing

There are no off or on switches on either box. Once the batteries are installed, they are active. Turn the transmitter box on its side so that its antenna is pointing to the left; observe the receiver. Now turn the box so that it is on its back or front. The receiver light should change. (See the demo video in the NV downloads.)

## Mounting

The transmitter should be mounted with the antenna horizontal and pointing left. If there is only one garage door, it can be mounted with double-backed Velcro tape. As the door tips activating the tilt switch, the transmitter will transmit. If you have more than one garage door (up to three), you can use a magnetic switch on the doors and connect them to the three terminals in the box. (Check

out Digi-Key CKN6004-ND.) Terminal one is common ground. Cut the trace coming from the tilt indicator. Again, mount the box with the antenna horizontal.

The receiver should be placed on either side with the antenna also horizontal. If the switch is pressed, the unit will act as an alarm if the doors are open.

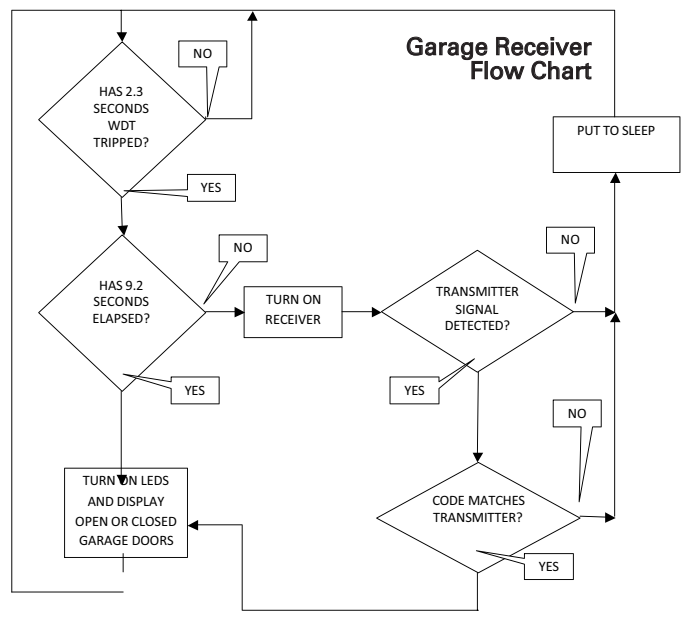
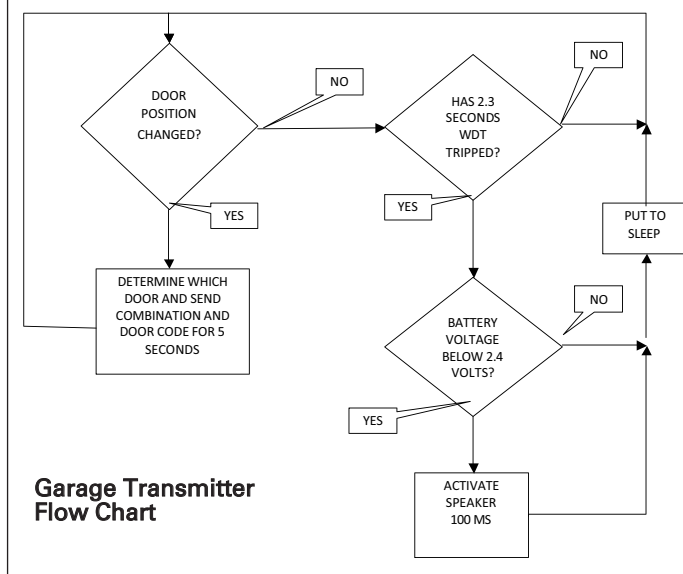
## Software

The program files are also located on the NV website. It is best to download MPLAB IDE from [www.microchip.com](http://www.microchip.com) to program or make modifications. They are labeled Garage Transmitter.asm and Garage Receiver.asm. See Figure 6 for the flowchart.

## Programming

You will need a PIC II programmer for programming.

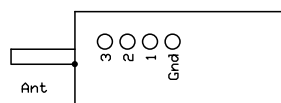
■ FIGURE 6.







S1 is tilt switch cut trace if using magnetic switch



■ FIGURE 7.

■ **FIGURE 7.**

cathodes are tied together; reversing the pins from Vss to Vpp will determine what their color will be depending on their input pin. (See **Figure 7**.)

Voltage detection is accomplished using a Microchip voltage detector with a 2.4 volt open drain. This is connected to an input pin which has an internal pull-up pin. When the voltage drops below 2.4 volts, it pulls this pin to ground. The WDT checks this every 2.3 seconds. If the voltage is low, the program jumps to the speaker program. This code produces a 2.7 kHz square wave for 100 milli-seconds (thus giving more of a click to save

power), indicating that the battery needs changing.

## Using More Than One Transmitter

If you are going to use more than one transmitter, make sure all the transmitters have the same combination.

Go to lines 62, 63, and 64, and swap S1 or S2 with Tilt, e.g., put Tilt in place of S1 (62) and move S1 to the Tilt (64). Now the receiver will read the new transmitter as S1. If you have trouble locating parts, there is a parts source on the website. In upcoming months, watch for

hacks for this project posted in the feature article section on the *Nuts & Volts* website. Happy transmission!

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PS- We were going to mention broken C-3PO on Chewbacca, but that was more of a mesh than a backpack.

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## PARTS LIST

### TRANSMITTER

ITEM	QTY	DESCRIP/SOURCE
Antenna	1 ea	ANT-418-PW-LP/ Linx
Battery Holder	1 ea	2 AAA
Box	1 ea	221/Serpac
C1	1 ea	10 $\mu$ F 16 volt
IC1	1 ea	PIC16F505 Microchip
IC2	1 ea	TRM-418-LT Linx
S2	1 ea	RBS070500T OncQue
Speaker	1 ea	GT-0903A Soberton, Inc.
Terminal 1-4	2 ea	276-1388 RadioShack
Voltage Detector	1 ea	IC VOLT DET 2.63V Microchip

### RECEIVER

Antenna	1 ea	ANT-418-PW-LP Linx
Battery Holder	1 ea	2 AAA
Box	1 ea	221/Serpac
C1	1 ea	10 $\mu$ F 16 volt
IC1	1 ea	PIC16F505 Microchip
IC2	1 ea	TRM-418-LT Linx
Opto 1-3	3 ea	Bi-colored LEDs
R1, 220 ohm, 1/6 watt	1 ea	
Speaker	1 ea	GT-0903A Soberton, Inc.
S1	1 ea	PVA1 EE H4 C&K Components
Voltage Detector	1 ea	IC VOLT DET 2.63V Microchip



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# Oscilloscope Probes and Probing

So, you made a great deal on eBay for a quality wideband oscilloscope along with some decent after-market probes, and UPS has just dropped it off at your doorstep. You anxiously tear open the package, power the scope up, and spend the next two hours at your test bench familiarizing and checking it out with your function generator. Everything works and appears to be correct — great! Now it's time to examine the operation on a host of prototypes you have completed recently. Time to see the real deal on how these circuits are actually performing — things that your old worn-out Heathkit scope's results could never have been trusted for.



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## Eeks : Problems!

The first circuit you look at with one of your 10X probes is a wide band amplifier. The results are disastrous. The frequency response is terrible; rising and falling in amplitude across the spectrum and with a much lower bandwidth than expected. In a cascaded section, one amp's output is too high and the following amp's output is actually lower than the one feeding it. Yikes! You switch to another probe and get the same results! You also notice that at the higher frequencies, moving the probe or cable changes the displayed amplitude. Next, you frantically look at another prototype containing an oscillator and a couple of buffers to an output jack. Connecting a probe from channel 1 to the output jack verifies that a signal is present there. You connect a probe to the scope's channel 2 and probe a section in the oscillator and see no signal at all. How can that be as you previously saw an output at the output jack?

Looking back at channel 1, the former signal is also missing. Moving the channel 2 probe to a different section of the oscillator, you now see a signal on both channels and at this point are somewhat confused. One last prototype that is supposed to produce fast rise time pulses is probed and the rise time is much slower than expected with a lot of overshoot and ringing at its leading and trailing edges. Oh no, you are thinking. My prototype designs are terrible and the new scope is defective! Well, don't throw your protos in the trash bin and send the scope back to the seller just yet.

If your scope passed your initial tests, it's probably working okay. If you have done similar protos in the past, then for the most part, they are probably doing at least a fair job. There is a very good chance that the problems lie in your probes and/or your probing!

## Examining the Source of the Problems

You are probably thinking that since the scope has a 300 MHz bandwidth and the probes are rated at a 250 MHz bandwidth with a 1.4 Nsec rise time, they should give good performance up to 200 MHz and beyond — which they will under the right conditions. The key word here is *right*. Let's cover a few things before we dive into probes. An oscilloscope's rated bandwidth is the point where the displayed signal amplitude vs. frequency drops to -3 db (70%) of its DC or very low frequency value when a leveled sine wave source is feeding the vertical pre-amp(s). In scopes that follow a Gaussian response curve (and almost all do), this will follow a very flat frequency response to 1/3 of its rated bandwidth and then drop at an increasing rate to its -3 db point (i.e., 300 MHz bandwidth; DC to 100 MHz flat response). However, this doesn't mean that there won't be peaks and dips along the way. In quality scopes, these are minimized. A probe with the same bandwidth spec as



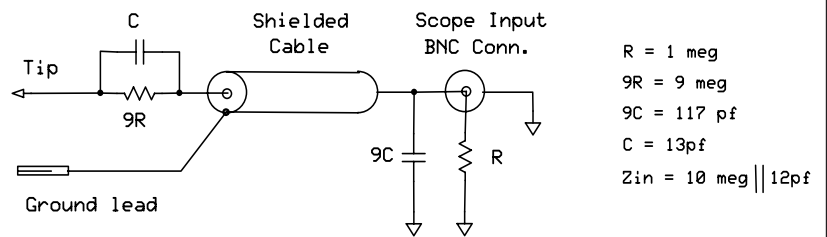
the scope may degrade this performance by virtue of its -3 db BW adding to the scope's -3 db bandwidth, therefore intensifying the loss at the limits of their individual stated bandwidths. Some manufacturers design probes to match their line of scopes to preserve their rated bandwidth or even extend it slightly. Now let's look at how a probe gets its rated bandwidth specs. This is done in a lab environment using sine wave generators with a 50 ohm source impedance immediately terminated with a 50 ohm load that has a BNC jack built into it. The ground lead and clip tip (witch's hat) are not used in this setup, but rather the tip has a special tip-to-BNC adapter that matches up to the termination jack. This effectively removes most problems associated with ground leads (as will be discussed later). Also, the probe tip is looking into an equivalent 25 ohm impedance by virtue of the generator source impedance (50) in parallel with the termination impedance (50). This constitutes an almost ideal condition for measurement, but rarely is the normal setup for probing in the real world.

**Figure 1A** shows a typical 10x passive probe connected to the scope's vertical input and the standard 10 megohm input resistance that it presents to all circuits probed. It also presents a capacitive load on those circuits. This is the series combination of C and 9C. The typical capacitance the circuits under test will see at the tip will range from 10 to 14 pF, so I will use 12 pF as a middle of the road spec. Scopes have a certain amount of inerrant input capacitance, along with the probe's cable, etc., connected to it. To obtain a flat frequency response in a resistive divider network, the time constant of the probe's attenuator network (9R in parallel with C) must exactly equal the time constant of the probe cable and scope input values (R paralleled by 9C). Since the probe's tips are constructed with a fixed value of resistance and tightly controlled parasitic capacitance C, the RC values on the scope end must be adjusted to exactly match this. This is done with a capacitive trimmer mounted in a termination box which is attached to the cable's BNC connector for the scope.

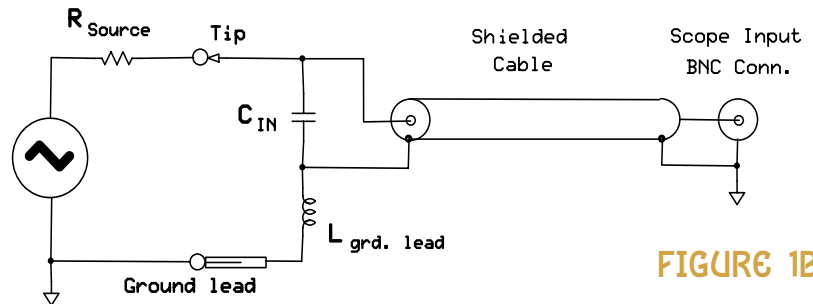
As mentioned, 9C is the combination of scope, cable, and trimmer capacitance. In the circuit shown, R probe = 9 megohm; C probe = 13 pF, and R scope = 1 megohm. Therefore, 9C must equal 9x13 or 117 pF to match the two time constants involved. With the aid of the scope's calibrator, 9C is adjusted to present the traditional "perfect square wave" on the display.

With an input signal of DC to very low frequency sine waves (<100 Hz), the probe's input impedance is basically all resistive and presents a 10 megohm load on the circuit being probed. At approximately 1,500 Hz, the probe's input R and Xc will be equal in magnitude, and probe input Z will be reduced to about 70% of that 10 megohm value. Input Z will continue to reduce with increasing frequency injected

**FIGURE 1A Typical 10X Passive Probe**



**Probe Characteristics at High Frequencies**

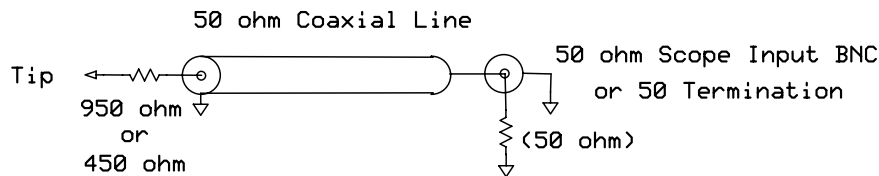


**FIGURE 1B**

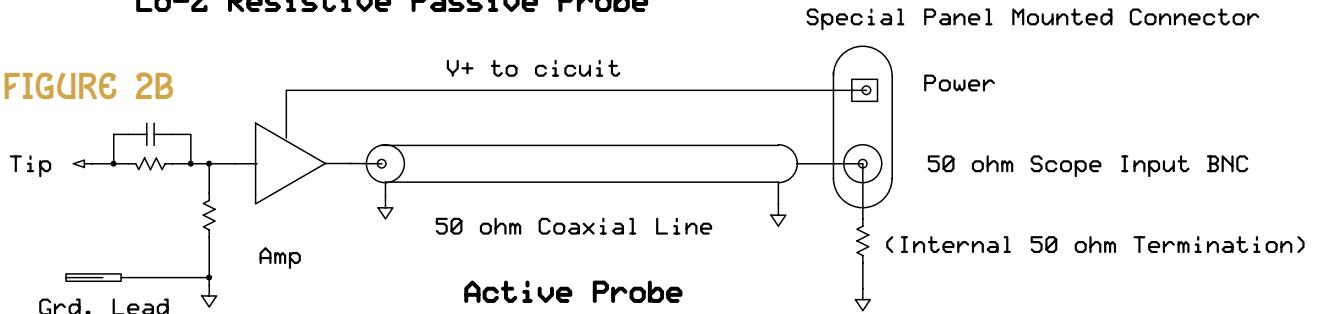
into the probe tip. However, due to the matched RC time constants in the probe's divider network, the 10:1 division ratio will be maintained. The probe will continue to give good performance up to 10 MHz and beyond, but as it enters the VHF range (30-300 MHz), problems start to occur. Referring to **Figure 1B**, the probe appears to the circuit as shown, when probing these higher frequencies. In this region, the probe's resistance no longer enters the picture as the magnitude of impedance is almost totally capacitive (when using a very short direct ground connection). Also, the XL of the clip tip begins to be of some significance, but even more so is the increasing XL of the ground lead attached to the probe. These two components (C<sub>in</sub> and L<sub>ground</sub>) will form a series resonant circuit at some point which can really mess up measurements. Even the best of probes have a resonant point regardless of the grounding system used.

High-end probe designers are constantly trying to move this resonant point up higher in frequency to push it up and well outside of the passband of the equipment being used. Small values of distributed 'L' and 'C' may be inserted at key points to flatten out response and raise the input impedance, but even with the best efforts, this will only show a certain degree of improvement.

So, in light of these facts, what do we end up with here? It is evident that in high frequency circuits, the probe's Xc is decreasing and loading the test circuit more. At the same time, the XL of the ground lead is increasing and, at some point, will resonate with C<sub>in</sub>. Also, the cable ground potential at the scope end is not the same potential as the probed circuit ground at the other end due to the ground lead's (typically 5-6") impedance. The scope faithfully displays its input signal, however that is only the signal that appears across C<sub>in</sub> (in **Figure 1B**). The probed circuit is applying its signal across both C<sub>in</sub> and L<sub>grd</sub>, thus producing a voltage divider action (along with some other nasty things) at the actual scope input. At some point, the signal resonates


**FIGURE 2A**

### Lo-Z Resistive Passive Probe

**FIGURE 2B**


### Active Probe

with  $C_{in}$  and  $L_{grd}$ . Since a series resonant circuit produces a dead short across its terminals (in an ideal world), this puts a tremendous load on the probed circuit and greatly reduces signal amplitude. Oddly enough, since each leg (L or C) has maximum current and impedance at resonance, the voltage will soar across these components causing a very high displayed screen level when in reality, the circuit's signal level is at its lowest point.

In my experience, most 10X probes will resonate in the 70 to 110 MHz region and will be somewhat subjective to the signal source R and C values. Due to those values, the resonant point can narrow, broaden, and or have a major or minor effect on signal amplitude. The probe's reactance can also add horrendous overshoot and ringing, along with slower rise times on displayed square waves that otherwise are not present. Three things happen when a probe is attached to a test circuit:

- 1) The circuit's signal is altered.
- 2) The signal is divided and distorted at the junction of  $C_{in}$  and  $L_{grd}$ .
- 3) The signal sent to the scope's vertical input will not be an exact reproduction of the signal present at the test circuit's signal in normal operation.

The magnitude of these effects are dependant on the probe, the circuit under test, and the signal's frequency content, making measurements quite unpredictable!

Now that we are armed with this new information, let's go back and review the 'problems' we had earlier with those prototypes. First, the wide band amplifier is a simple circuit with a 300 ohm collector load. When operating at 150 MHz, the probe has a loading effect of <100 ohms  $X_c$  across that resistor. This load drops the amplifier output to 30% of what was really there. When operating with a 90 MHz signal, the probe is deep into resonance producing a much higher displayed signal than expected. Again, not really there in normal operation. Similar results are falsely displayed on subsequent stages of that proto.

In the oscillator circuit, the first point probed was in a critical feedback leg and the probe's  $C_{in}$  to ground totally killed oscillations. The second point in that circuit was less critical and oscillations survived albeit with a large shift in

frequency. The fast rise square waves have been slowed by the probe's loading capacitance and ring at the probe's resonant frequency. So, it's bad enough that the displayed wave forms may not always follow what the probe is seeing but also, the connected probe is altering the test circuit operation. Worse yet, the results are unpredictable.

## What You Can Do About the Problems

The first thing is to remove the clip tip to reduce series inductance, and use the shortest ground lead possible for the same reason. If possible, try to probe lower impedance points in the circuit to reduce loading effects. As far as probe resonances, they are most prominent at source impedances below 50 ohms, having lesser effects with source impedances above several hundred ohms. For the low Z sources, a low ohm value tip resistor can be added to dampen the resonant point. A 1/4 watt resistor wrapped around the tip and with the other lead cut short will suffice. This resistor now becomes the 'new' tip. Generally, this value will be in the 50-100 ohm range. Lastly, I do a thorough study of the circuit under test to try and predetermine the results of adding a probe to that circuit. These suggestions are a rule of thumb rather than an ideal 'cure-all.'

There are two types of probes that will overcome most of these problems. One is the low Z passive probe shown in **Figure 2A** and the other is the active probe shown in **Figure 2B**. The first one is cheap and easy for home construction. It is merely a 1/4 watt carbon resistor soldered to the end of a 50 ohm coaxial transmission line with a mating BNC connector at the opposite end. The resistor leads should be cut short and act as the probe tip. The coax ground lead at that point should also be kept relatively short. These types of probes are much more immune to ground leads effects than other probes, but when making very critical measurements, that shield should be temporarily tack soldered to the circuit's ground.

The upside of this probe is that it is "king of the hill" for high speed probing, and has superior fidelity, very fast rise



time, and very wide bandwidth. The downside is heavy loading and a high probe attenuation factor. For the two values of R shown, the attenuation is 10X with 450 ohms and 20X with 950 ohms. Also be aware that it is DC coupled. Ideally, these connect to a scope's 50 ohm input port (which most quality scopes with >150 MHz BW have). In lieu of that, a 50 ohm termination will have to be added between the scope's normal one meg input jack and the probe's BNC termination. Unfortunately, the scope's approximate 20 pF of input capacity at this port will still be present under this situation and will present an increasing VSWR vs. frequency, skewing results above 100 MHz. In spite of this probe's shortcomings, it has very low input capacitance (<1 pF), thereby presenting an almost purely resistive load to the circuit under test; VHF frequencies and above will actually have less loading effect than the aforementioned 10X passive probes. As cautioned, the probe is DC coupled but is actually an advantage in standard five volt logic circuitry. In my experience, there was a 20% loading factor in probing high speed CMOS logic devices, but the fidelity is preserved and predictable.

The active probe is shown in simplified form in **Figure 2B**. Typically, the probe initially couples the signal through a very small coupling capacitor (although some are DC coupled through an RC network) into a high input impedance amplifier. The input network is adjusted to give a 10:1 attenuation ratio with a very small  $C_{in}$  (<1 pF). The amplifier will have a gain of X1 to X10. This gives the probe an attenuation ratio of anywhere from 1X to 10X. It is rare to find these probes with a 1X configuration (no attenuation).

More commonly, they will be in a 5X or 10X configuration. In all cases, the output is converted to 50 ohms Z and sent down a 50 ohm transmission line to the scope's vertical input. The down side of these probes include the Bulky probe tip (in some models), external DC power required, limited dynamic range, and a shocking sticker price averaging \$2,000 to \$3,000. The highest priced one I ever saw came in just under a whopping \$16,000.

Their upsides are superior bandwidth (some >10 GHz), excellent rise time, and high R/ low C probe input specs. However, these phenomenal specs do not come without some strings attached. When dealing in precise and faithful probing in the realm of microwave frequencies that these probes are capable of, the probe's accessories and techniques become almost as important as the probe itself to insure quality results. Depending on the probing situation, special grounding adapters have to be used and special resistive probe tips have to be interchanged (as many as a dozen or more). In some cases, special sockets have to be installed and soldered directly to the circuit board which will mate up to an accessory probe tip. Include a thorough understanding of the circuit being probed so that the correct accessories will be installed and it's easy to see that these high-end probes are not for the amateur.

Constructing one of these probes at the hobbyist level would be very difficult to say the least. However, in spite of the shortcomings of the common 10X passive probes, they are still the workhorse of the industry and are very worthwhile for general-purpose probing. Their dynamic

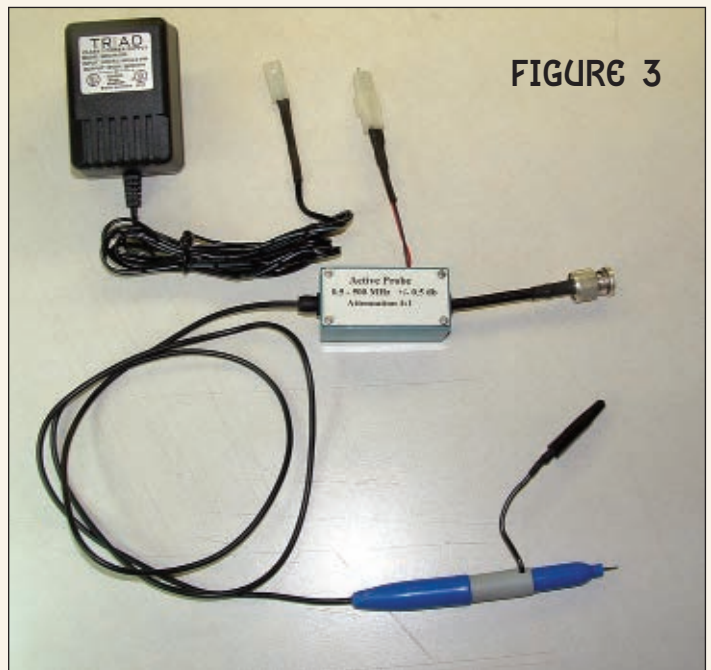
range far outpaces any other type probe made and often approaches upper limits of 500-600 volts. I would always include a couple in my arsenal of probes.

## What I Did About the Problem

I have always been intrigued by the concepts of the low Z passive probes and active probes. After years of frustration using the common 10X passive probes, I decided it was time to switch to one of these superior probes. Since I could not justify the expense involved in a commercial product, I thought I would design and construct one myself. Each probe has its benefits and drawbacks. The low Z has excellent fidelity, rise time, and bandwidth but gives way too high loading and attenuation. The active probe also has these great features but with the added benefit of low loading and low attenuation. However, it comes with the added burden of a bulky probe size (in my design), limited dynamic range, necessity of external power, and difficulty constructing and calibrating the input network. In mulling over the various pluses and minuses of these probes, I decided to construct a hybrid of the two, which I humorously call the "Passive-Active" probe. **Figure 3** shows the completed unit.

The probe starts out in the traditional low Z style with a resistive divider feeding a 50 ohm transmission line, but with one exception: a much higher input impedance (i.e., 3,400 ohms as opposed to 1,000 ohms). This is fed to an active probe's traditional amplifier circuit before being applied to the scope's input. The amplifier makes up for most of the divider losses. This probe still suffers some of the unavoidable consequences of its commercial counterparts, such as a limited dynamic range, moderate circuit loading, and necessity of external power.

Due to design constraints, the optimum dynamic range was determined to be 8V p-p input at its upper end with the low end of that range being 15 mV p-p input to obtain two divisions of vertical deflection (typical sensitivity for wide



**FIGURE 3**

band scopes). This should handle the normal range of signal levels encountered in high frequency circuitry. It will not handle very low amplitude signals applicable to radio receiver circuits, but that is a job intended for spectrum analyzers only.

As to circuit loading, there really are no high impedance circuits once we enter the VHF spectrum and above. Normally, most circuit source impedances will range from 25-500 ohms at these frequencies. Even reactive LC circuitry will have much lower impedance comparable to low frequency counterparts. So, the 3,400 ohm loading factor of this probe will pose an acceptably small loading on most VHF circuitry. And more importantly, it imposes a very small reactive loading ( $>>1$  pF). In high frequency measurement, the probe's reactive component is much more critical than its resistive one in terms of circuit loading (as explained earlier). Finally, as to external power, this turned out to be of little inconvenience due to the amplifier's onboard regulator and power plug. It required only a separate wall plug transformer of adequate voltage. I leave this wall wart plugged into an outlet strip mounted on the back of my scope cart. This makes probe installation quick and easy — just one added cable to connect/disconnect.

## Probe Design

In designing this probe, a number of factors had to be considered. It all starts with the MMIC (monolithic microwave integrated circuit) amplifier which has a gain of 31 db (X34), a 1 db compression point (the very onset of saturation) of 12.5 dbm (approx. 2.5V p-p), and a frequency response roll-off of -4 db at 500 MHz. It also requires a 50 ohm source and load impedance to maintain these specs, along with good stability. Best performance with these amps is obtained with a bias (B+) current of 36 mA. The B+ supplying this current ideally would be through a load resistance of infinite impedance because this load is effectively placed in parallel with the 50 ohm termination impedance. A constant current source comes to mind but will not work here as per manufacturer's application notes. If the bandwidth ratio was not quite so wide, a suitable RFC (radio frequency choke) could be used with a bias supply of 5 VDC. However, this circuit requires a very wide bandwidth ratio (1,000:1); no RFC would work due to their inherent self-resonance at some point, rendering them useless at frequencies above that. So, a pure resistance is

required here to supply the bias current and I want that value to be as high as possible. Of course, the higher the resistance, the higher the supply voltage has to be to supply that current. A compromise had to be made here in terms of voltage, wattage dissipation, and shunt loading. I chose 18 volts which works out to 392 ohms for the supply resistor with a dissipation of 1/2 watt, without upsetting the output termination to a great degree.

Given that 392 ohms is not the ideal value here, the amp's maximum output level is degraded, so I decided to spec that figure at +10 dbm (2.0V p-p) for best linearity. Given the amplifier's gain with a 1:1 attenuation ratio, this would only allow for a max probe input impedance of 850 ohms and its dynamic range limited to 2.0V p-p on the upper end. These limits just would not satisfy a wide range of probing situations, but by increasing probe attenuation to 4:1, I could get the 8V p-p input level I was after at the upper end of range, and increase the input impedance to 3,400 ohms. The actual input impedance works out to 3,400 ohms shunted by  $<<1$  pF. This provides an acceptable loading factor while maintaining the desired dynamic range.

It now becomes a 4x probe and it is easy to calculate the actual display amplitude vs. input signal amplitude — just double the displayed voltage and double it again (X4). Not as easy as a 1X or 10X probe, but still quite simple to compute in one's head. The amplifier roll off, cabling connections, and board layout combined will add up to a little less than a -6 db (2x) loss at the upper limit of 500 MHz of the probe's bandwidth, so the next problem to be solved was how to flatten this response curve. The straightforward answer was to shunt R1 and R2 with a compensation capacitance. The Xc needed for this compensation worked out to be 2,000 ohms at 500 MHz which has a value of 0.18 pF. It worked out in my favor on this one due to the fact that 1/4 watt carbon film resistors have a parasitic capacitance of 0.35 pF. Two in series would give me 0.175 pF — almost exactly what I needed! A call to KOA Speer's (resistor manufacturer) engineering department confirmed that these resistors are made to exacting mechanical tolerances and that the parasitic is uniform from unit to unit with one minor exception. The laser etching used in the manufacturing process is slightly different from one group of values to the next; a group value being a certain range of resistance in perhaps a 5:1 ratio.

Next I needed to pick out two values of resistance that would give me a combined value of 3,400 ohms and a

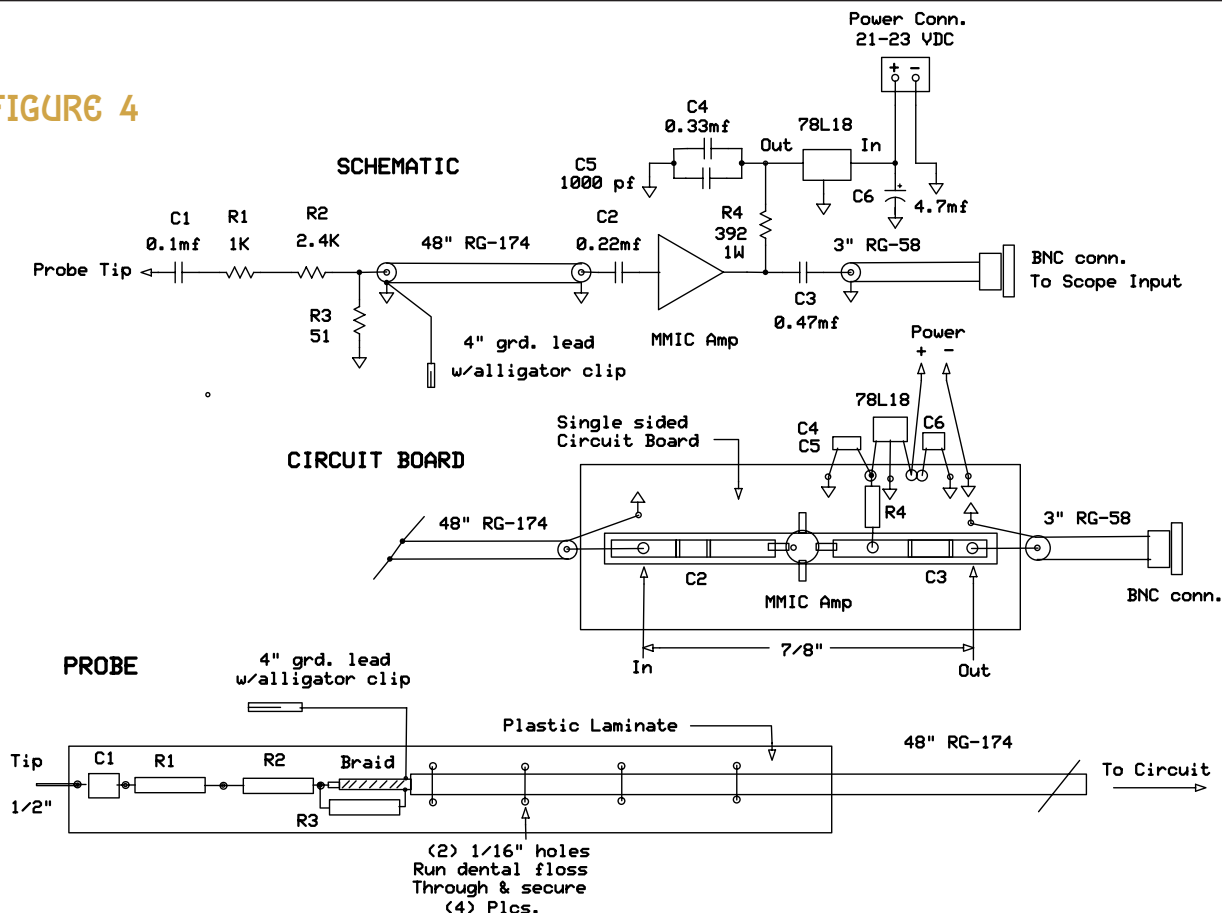
parasitic capacitance of approximately 0.175 pF. The values chosen were accomplished empirically due to the fact that the exact capacitance could not be predetermined. After considerable experimentation, a set of values was found to be 1,000 ohms in series with 2,400 ohms, with the correct parasitic capacitance to flatten out the response

ITEM	DESCRIPTION	SOURCE
C1	0.1 MFD/50V MLC ceramic	
C2	0.22 MFD/50V chip size 1812	
C3	0.47 MFD/50V chip size 1812	
C4	0.33 MFD/50V MLC ceramic	
C5	1,000 pF/50V MLC ceramic	
C6	4.7 MFD/50V tantalum electrolytic	
R1	1,000 ohm 1/4W carbon film	Mouser.com p/n 600 - CF 1/4 102J
R2	2,400 ohm 1/4W carbon film	Mouser p/n 600 - CF 1/4 242J
R3	51 ohm 1/4W carbon film	
R4	392 ohm 1W 1% metal film	Mouser p/n 71 - CMF60392R00FHEK
MMIC	MAR-8A mini-circuits	
18V Regulator	78L18	
Wall plug		
Power Pack	Triad 18V/300 mA	Mouser p/n 553-WDU18-300

### Active Probe Parts List



FIGURE 4



curve. To confirm what the manufacturer told me, I tried out several sets of these and got identical results. I also tried out some others from different manufacturers and the results were very close. Just to be on the safe side though, stick with the numbers in the **Parts List**. The final specs on the probe work out to this:

- Attenuation ratio: 4:1 (4X probe)
- Frequency response: 0.5 to 500 MHz  $\pm 0.5$  db
- Maximum tip input: 8V p-p
- Input impedance: 3,400 ohms - 0.2 pF

- Probe tip impedance: 3,400 ohms -  $< 0.5$  pF
- Rise time  $< 500$  pF
- -3 db point  $> 750$  MHz (estimated)
- Resonance:  $> 1$  GHz (estimated)

## Probe Construction

The construction of this probe is quite simple and low cost. I had an old Pomona box laying around that I used for the active board enclosure. The cables came out of my junk

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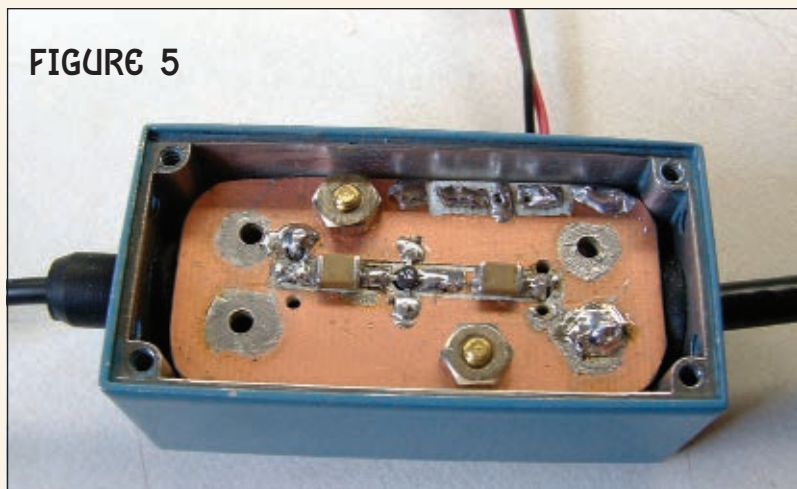
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**FIGURE 5**



box and were cut to proper length. I paid \$20 for the remaining parts needed. The wall plug transformer was the most expensive at \$10. The probe components are installed in a modified Sharpie felt tip pen housing. The cap was removed and the pocket clip snipped off flush with the body. Then, a 1/8" hole was drilled into the end to accept the RG-174 cable. I then removed 1" of material from the end of the pen body, reached in with needle-nose pliers, and removed the ink cartridge. The protruding felt tip was then snipped flush with the end of the body. I stood the body up straight on a firm surface and got the remaining felt out by driving it back into the housing with a hammer and punch (a flat end nail of the proper size will also do). A little cleanup work was needed inside the housing, so I used

various drill bits and rotated them by hand to remove the remaining plastic nibs. The housing will need a thorough cleaning to remove any remaining ink residue; the process can be a bit messy. I used a piece of plastic laminate (Formica) shaped to fit the interior all the way to the tip. Although **Figure 4** shows this as a rectangular shape for drawing simplicity, the finished piece will be more bullet shaped near the tip end. The components C1, R1, R2, and R3 are all thru-hole components. Since a copper-clad board has too much stray capacitance, these parts lend themselves to better support in this application.

After I was satisfied I had a good fit in the housing with the laminate, I pre-drilled all the mounting holes. The actual probe tip was a broken

needle from my wife's sewing machine and it takes solder quite readily. This was soldered to one lead of C1 with its other lead dropped through its board hole and yanked back to hold it in place. The probe tip is then positioned on center with about 1/2" exposed beyond the laminate. A blob of epoxy cement is dropped on it to preset it. When cured, another blob is smeared over it again and half of C1, and is allowed to flow around both sides of the board. This gives the tip adequate support when cured. The component leads are dropped through their corresponding holes; their leads bent back and joined with a healthy dose of solder. When cooled, snip these flush with the board. The exposed section of the cable braid is actually pinched back to form two solder nibs where R3 and the ground lead connect; then get it pre-tinned.

Attach the RG-174 cable and secure it down with dental floss (the waxed type is best). Drill a thru-hole in the probe body at an appropriate spot for the ground lead to protrude. Push the ground lead through it from outside the housing and far enough so that the protruding end sticks out far enough to allow soldering to the cable's ground braid when the probe board is partially inserted into the housing. When completed, the probe board is pushed in all the way until it is snug. Apply a slight pulling force on the ground lead while doing this. There should be about 3/8" of probe tip protruding from the housing end. In my probe, friction was all that was needed to keep it in place. Some wadded, non-conductive material would have been jammed into the open end had this not been the case.

The back of the probe body needed a little abrading to accept the cap with a nice snug fit. The finished active circuit is shown in **Figure 5**. This circuit starts out with a piece of 1" x 2" single-sided copper-clad board. A trace 3/16" wide x 1-1/4" long was etched right down the center of it. A couple of small islands were also etched out at the upper right corner to accept the regulator (TO-92) and its associated components.

On the long trace, a 1/8" hole is drilled where the MMIC amplifier will reside. This is located about 1/4" off center to the left along the axis of that trace. The remaining copper area at the edge of the hole was then removed to completely break the trace's path. Also, two breaks were etched out where the chip capacitors will be installed. (A note here: When I refer to etching, I mean etching with a

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rotary tool, knife, or whatever.) The remaining thru-holes were drilled and the remaining components were mounted. R4, C4, 5, 6, and the regulator are all thru-hole components and mounted from the other side of the board (phenolic side). The R4 lead length is not critical, just make sure it fits.

The MMIC amp has one tapered leg with a corresponding color dot on its case — this is the RF input terminal. This was then soldered into place along with the two chip capacitors C2 and C3. Depending on the enclosure used, the cable installation will vary. In my case, the cables pass through grommets in each end, and were pushed through the enclosure before soldering them to the circuit board. In prepping the cable ends, keep these leads short. Expose only about 1/8" of insulation on the center conductors. Twist the braids to form a wire for the ground lead, then push these leads into their corresponding holes and solder them to the board as close as possible. Ideally, there will only be about 1/8" of exposed wire/insulation at these connections. After all the soldering was completed, the board was secured to the enclosure on two pre-installed 1/2" standoffs. One final comment about overall construction — plan ahead and after every machining operation, make sure the respective parts fit as intended before proceeding with soldering. Add the final power leads, connectors, etc., and the probe is ready to use. A word of caution here: Double-check all connections and polarities before initial power-up as the MMIC amp operates at 4 VDC and will not tolerate reverse polarity when fed from an 18 volt supply.

## Testing the Probe

For a simple circuit, this probe required many dozens of tests throughout its design cycle to verify performance vs. circuit changes, so it came as no surprise to me that the finished unit operated as expected. In that cycle, various ground lead lengths of 1" through 6" were tried with only small changes in performance. Even though ground leads degrade performance somewhat, I wanted one for convenience of use. After some consideration, 4" was the best compromise and the circuit was optimized for that. This works because the low Z style probe is much more immune to ground lead problems than other style probes. With everything completed, the probe should work as advertised, but I still ran a battery of tests with capable test equipment to

verify that. Upon completion, it would be reassuring if you could do the same even if you had to temporarily beg, borrow, or steal the necessary equipment to do so. One thing I want to point out here is that the probe has a 50 ohm output impedance and will perform best with scopes that have a 50 ohm vertical input port (most scopes having >150 MHz BW have this port). In lieu of this port, there are 50 ohm BNC/BNC terminations available that can be attached to the standard 1 meg vertical input jack. Bear in mind that using that input, there will be an increasing VSWR with increasing frequency due to the scope's 20 pF of input capacitance at that jack. So, displays will be somewhat skewed above 100 MHz. Upon completion of this probe, I ran side by side comparison tests against a variety of my common 10X passive probes. The tests were performed on



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a variety of commercial circuits that had known and documented signal levels at various frequencies from 10 to 500 MHz. The passive probes performed well up to 10 MHz and fair up to 25-30 MHz on most circuits, but not all. Once I entered the VHF region (30 -300 MHz) all bets were off as the CRT displays were becoming erratic and unpredictable. At times, they registered only 20% of the actual amplitude level and at other times, the levels were much higher than the true levels. By comparison, the active probe performed very well in all circuits probed, giving a very close display to all documented levels. It only produced a small frequency shift (<1%) in sensitive areas of oscillator circuits as compared to the 10X probe (>8%). Also, the loading was quite good to acceptable in these circuits, but

that loading was also quite predictable (i.e., 330 ohm collector load - 3,400 ohm probe Z - 10% loading). The 3,400 ohm probe impedance may seem alarmingly low to you and it well may be for low frequency circuits, but this probe is designed for high frequency circuits above 20 MHz where source impedances tend to drop dramatically from lower frequency circuits. So, it's not as bad as it first appears – in spite of the fact that the probe's impedance reduces further yet at higher frequencies. Consider that this probe has an input R of 3,400 ohms paralleled by 0.2 pF which would yield an input impedance of 2,100 ohms at 300 MHz. The common 10X probe has an input R of 10 megohms paralleled by 12 pF. The 10 meg has no effect as the input is purely capacitive at this frequency, yielding an

input impedance of 45 ohms; it gets worse as the frequency goes up. The active probes impedance looks quite stiff by comparison. The rise time on this probe is excellent but unfortunately since this probe is AC coupled by necessity, it can only handle square waves above a few hundred kHz; increasing the coupling capacitor values would improve this but there are limits.

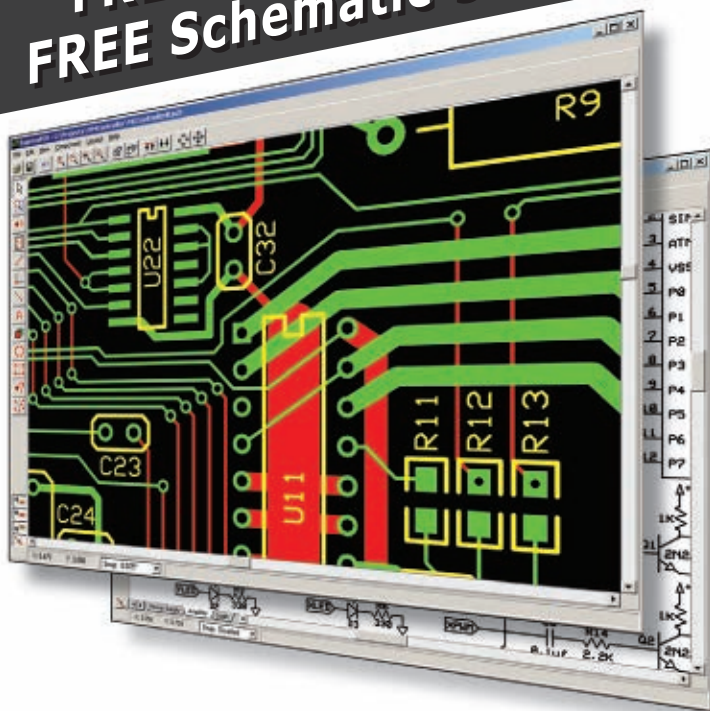
## Probing Tips and Thoughts

After using this active probe for a while, I have gained complete confidence in it and it has opened up a whole new world of investigation for me. It has also answered many unaccountable readings encountered in testing previous circuits that had mysterious operations. When using this probe (as well as any other probe), good high frequency techniques require that the probe cable be free of kinks and kept clear of the circuit under test. The probe tip should enter the test point perpendicular to the circuit board. Always grasp the probe near the cable end so as to minimize finger presence at the probe tip. Once again, I want to stress that the common 10X passive probe is the workhorse of the industry and a valuable asset to your collection of probes. But you must be aware of the fact that for other than general probing at high frequencies, many false readings will occur with it.

If you decide to build this probe, visit [www.koaspeer.com](http://www.koaspeer.com). It has a wealth of information in its application notes, along with case outlines and demo board layouts for the MAR-8 MMIC amplifier. There's also good info on a lot of their interesting products. **NV**

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### Short Circuits III Kit - Screamer Car Alarm

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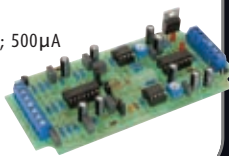


## SOLAR POWERED SHED ALARM KIT

### KC-5494 \$17.50 plus postage & packing

A lot of valuable items are stored in sheds or locations without access to mains power - a boat on a mooring, for example. What you need is a simple solar powered alarm that works with a variety of sensors - just what this kit does. It has 3 inputs, plus all the normal entry/exit delay etc. Short form kit only - add your own solar panel, SLA battery, sensors and siren.

Supply voltage: 12VDC  
Current: 3mA during exit delay; 500µA with PIR connected  
Exit delay: 22 seconds  
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Alarm period: 25s to 2.5 minutes adjustable



## SHORT CIRCUITS III KIT - LOW-COST INTERCOM SYSTEM

### KJ-8080 \$9.50 plus postage & packing

A low-cost method of communicating between two rooms. The remote unit is hands free so it's also great as a baby monitor.

- Kit includes PCB, speakers and electronic components.
- 12VDC required.
- PCB: 105 x 60mm

Instructions are NOT included. Instructions to suit Short Circuits III project - Low Cost Intercom Cat. KJ-8081 \$1.25. For full color instructions - see Short Circuits Vol III Book. Cat. BJ-8505 \$7.50



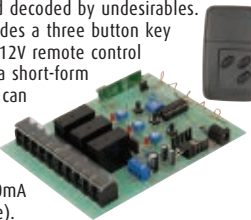
## UHF ROLLING CODE REMOTE SWITCH KIT

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High-security 3-channel remote control that can be used for keyless entry into residential or commercial premises or for controlling garage doors and lights. Up to 16 transmitters may be used with the one receiver so it's suitable for small-scale commercial applications. As it features rolling code / code hopping, the access codes can't be intercepted and decoded by undesirables. The transmitter kit includes a three button key fob case and runs on a 12V remote control battery. The receiver is a short-form kit without case so you can mount it in the location or enclosure of your choice.

- Receiver 12VDC @ 150mA (1A for door strike use).

Additional UHF Rolling Code Transmitter Kit KC-5484 \$23.25



## Ultrasonic Antifouling System For Boats

### KC-5498 \$124.50 plus postage & packing

Many of you know that you can buy \$2-5,000 imported marine growth electronic antifouling systems. Jaycar, with Silicon Chip have developed a similar system based on this technology and information in the public domain. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in sturdy polyurethane housings. By building yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. Research reveals only one transducer is needed for boats under 40ft. Basically all parts supplied in the project kit including wiring.

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### KC-5458 \$37.75 plus postage & packing

This excellent keyless entry system features two independent door strike outputs and will recognize up to 16 separate key fobs. The system keeps the coded key fobs synchronized to the receiver and compensates for random button presses while the fobs are out of range. Supplied with solder masked and silk screen printed PCB, two programmed micros, battery and all electronic components. The receiver requires a 12VDC 1.5A power supply. Some SMD soldering is required.



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- PCB: 123 x 74mm

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■ BY FRED EADY

# A UNIVERSAL MICRO DESIGN

**When I'm not writing, I'm soldering. With that, I figure most of you are not looking down the sights of a soldering iron as much as I am. So, instead of subjecting you to soldering up my *SERVO*-inspired experimental micro-SD card interface, I decided to design a simple and super-low-cost microSD interface card that you can build on your bench.**

**Our EDTP microSD Interface Card is wired to operate in SPI mode, thus allowing it to attach to any microcontroller capable of communicating via a SPI portal. However, you know me. If I went to the trouble of putting some fiberglass and copper under a microSD card socket, I'm going to come up with a microcontroller board to support the microSD card that gets clicked into that microSD card socket.**

## NO PIC18LF4620??

Nope. Not this time. The venerable PIC18LF4620 microcontroller that has supported so many Design Cycle projects is being kicked to the curb this month in favor of the USB-enabled and pin-compatible PIC18F46J50.

The J in PIC18F46J50 tells us that this particular microcontroller is USB capable. The PIC18F46J50 is also a member of the nanoWatt XLP family which means it sleeps hard drawing only 850 nA while running its built-in real time clock/calendar. If the PIC18F46J50's RTCC is not required, sleep current can drop as low as 13 nA.

Source voltages between 2.0 volts and 3.6 volts are welcomed by the PIC18F46J50. There are 15 5.0 volt tolerant I/O pins available if you choose to use the 44-pin TQFP version of the PIC18F46J50. Its PORTB and PORTC I/O pins retain the high current sink and source values of 25 mA that are normally found only on the 5.0 volt PIC variants. With respect to on-chip peripherals, the PIC18F46J50 generally has two of everything as compared to the PIC18LF4620. This is possible due to the inclusion of a feature called Peripheral pin select. Peripheral Pin Select allows the programmer to map certain PIC18F46J50 I/O pins to built-in peripherals.

*Fred Eady's First Rule of Embedded Computing* comes into play here. The PIC18F46J50 has more goodies than the PIC18LF4620. However, the PIC18F46J50 pays for these additional goodies with SRAM and EEPROM. The PIC18F46J50 rings in with 3,776 bytes of SRAM versus the PIC18LF4620's 3,986 bytes of SRAM and 1,024 bytes

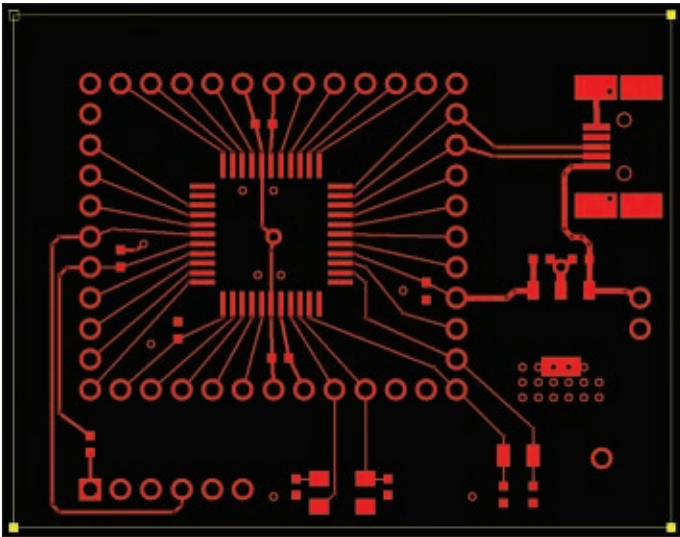
of EEPROM. Thus, as the *Fred Eady's First Rule of Embedded Computing* states, "Nothing is free." The PIC18F46J50 has the ability to redeem itself as far as its absence of EEPROM is concerned in that under program control, the PIC18F46J50 can emulate EEPROM with its program Flash. While both the PIC18LF4620 and PIC18F46J50 offer EEPROM alternatives, let us not forget that both microcontrollers can also deposit data into a microSD card ATM.

In a nutshell, the PIC18F46J50 is more versatile and fuel efficient than the PIC18LF4620. As far as firmware creation is concerned, the C programming language levels the playing field as the only programming differences in the PIC18F46J50 and PIC18LF4620 depend on which on-chip peripherals we decide to use.

## A UNIVERSAL PIC18F46J50 DESIGN

The only way that I can think of to create a "universal" microcontroller design is to make all of the microcontroller's I/O and peripherals available to the programmer/designer. Again, *Fred Eady's First Rule of Embedded Computing* is observed. The "universal" microcontroller design's printed circuit board (PCB) contains only enough electronic components to support the base operation of the microcontroller that is supports. That means that absolutely no external devices have access to the native universal design, which renders it virtually useless as an intelligent monitor and control device. To gain access to the universal design's



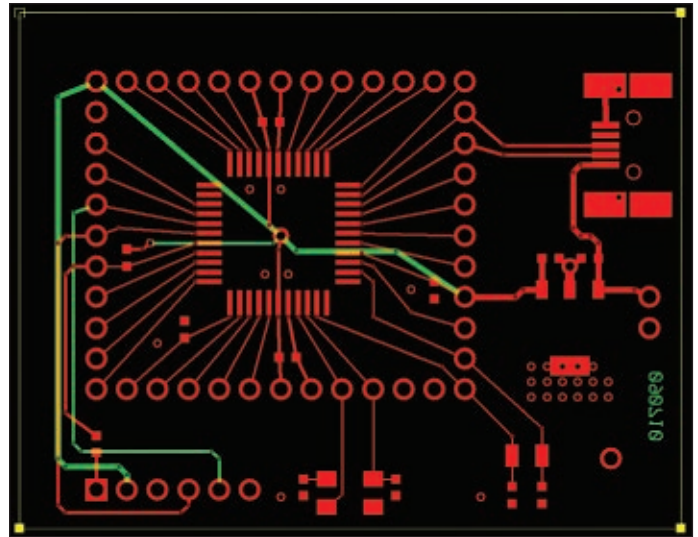
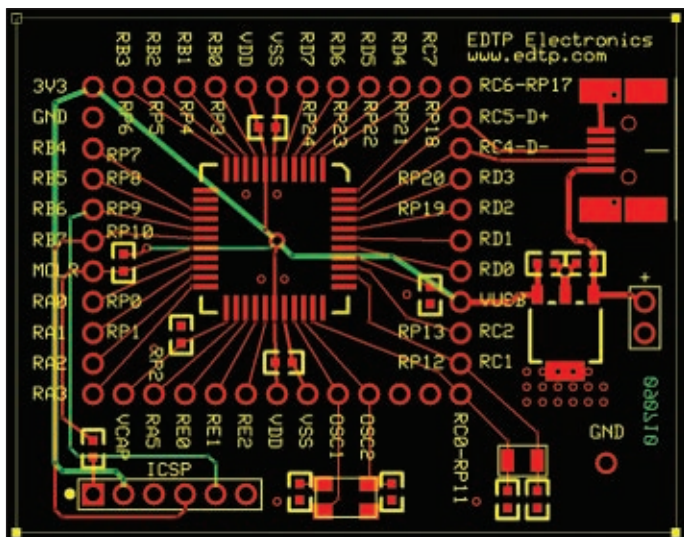


■ **SCREENSHOT 1.** This is the initial component layout. The silkscreen has been disabled to give you an unobstructed view of the top-side traces.

microcontroller, external devices must be attached to the design dictates. Since the universal design is built up on its own PCB, one or more peripheral device PCBs may be required. In reality, this turns out to be a good thing as most any design targeting the universal design's microcontroller can be implemented.

The PIC18F46J50's 44-pin TQFP package allows us to start our universal design small. The daughterboard captured in **Screenshot 1** measures in at 2.15 x 1.675 inches. The silkscreen has been disabled in **Screenshot 1** to give you an unobstructed view of the traces and the component locations. Only the PIC18F46J50 and 16 supporting components are mounted on the daughterboard. As you can see, the design is not at all complex and lends itself to an inexpensive ExpressPCB double-sided PCB. **Screenshot 2** shows just how simple

■ **SCREENSHOT 3.** This screenshot reveals a 3.3 volt voltage regulator that can be powered by the USB portal or an external power source. Powering from an external source while powering from USB is a NO-NO.



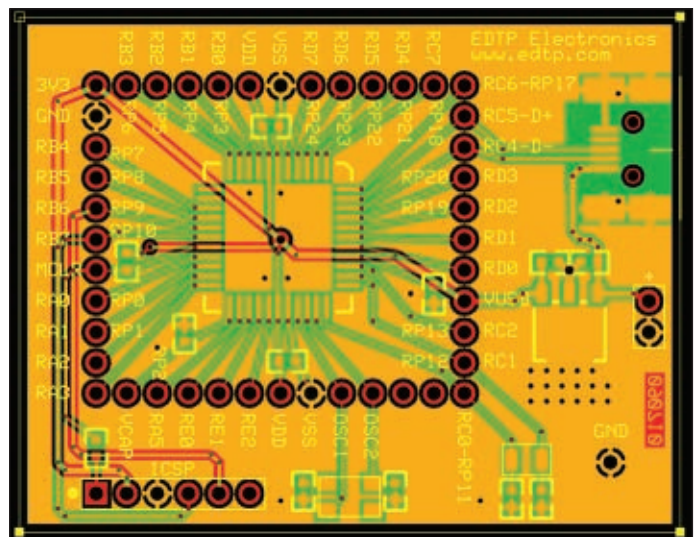
■ **SCREENSHOT 2.** Pretty simple, huh? The bottom-side trace pattern is minimal because the plane we will add later will make all of the ground connections on this side of the printed circuit board.

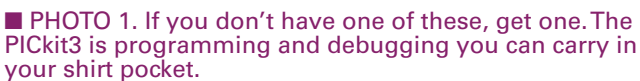
the PIC18F46J50 daughterboard design really is. Only four traces are laid in on the bottom side of the fiberglass.

It took a few iterations to come to the finality of **Screenshot 3**. With all of the components in their final positions, I silkscreened in the PIC18F46J50 I/O pin labels. To keep the silkscreen chaos to a minimum, I suppressed the silkscreen part identifiers. You can get all of the part's scoop by simply clicking on the part. I've provided the original ExpressPCB files in the article downloads for this purpose. All of the RPxx silkscreen legends call out pins that support the PIC18F46J50's peripheral pin select feature.

Note that the TC1262-3.3 voltage regulator can be powered from an outside source, as well as the VBUS voltage from the USB portal. The power sources are mutually exclusive as the USB specification states that the

■ **SCREENSHOT 4.** Everything is in place and the ground planes have been applied. Note that the ground planes are simultaneously used as ground traces and shields.

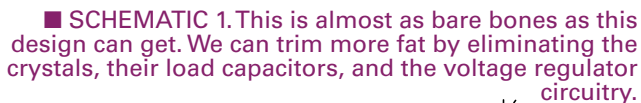




EDTP Electronics, Inc.; microSD Card Interface;  
USCM-46J50:[www.edtp.com](http://www.edtp.com)

I didn't double-label the OSCx pins. However, you can choose to use the PIC18F46J50's internal oscillator which would allow you to use OSC1 and OSC2 as RA7 and RA6, respectively. The pads for the 12 MHz crystal and its supporting load capacitors can also be left blank if you don't wish to use the particular type of FOX crystal I've designed in.

I've added filled planes on the top and bottom sides of the daughterboard in **Screenshot 4**. Both planes are ground planes. Note that I have used various thermal feed through pads and vias to electrically connect the ground planes and their associated electronic components. For instance, you'll find thermal connections that electrically





connect the top and bottom ground planes at the PIC18F46J50's VSS pins. Pin 3 of the ICSP portal is also a thermal ground feed through. Three other thermal feed through ground pads can be found at the pair of GND pads and the ground pin of the external power source connector. Good examples of feed through vias can be seen at the tab of the TC1262-3.3 voltage regulator. Feed through vias are placed everywhere a ground connection may be pinched off on the top-side ground plane. In all cases, the bottom ground plane uses the feed through vias to provide a ground path to the isolated top plane area. You can explore the various feed through vias, component connects, and thermal pads by altering the views of the ExpressPCB files in the download package and comparing the physical attributes of the PIC18F46J50 daughterboard to the graphics of **Schematic 1**.

Our universal design becomes truly universal when it is mated to external devices. To insure the success of that merger, all of the PIC18F46J50's header pads, the ICSP pads, the pair of thermal GND pads, and the external power input pads are all on 0.1 inch centers. A fully populated daughterboard is the focus of **Photo 2**.

## BUILDING AN EDTP MICROSD INTERFACE CARD

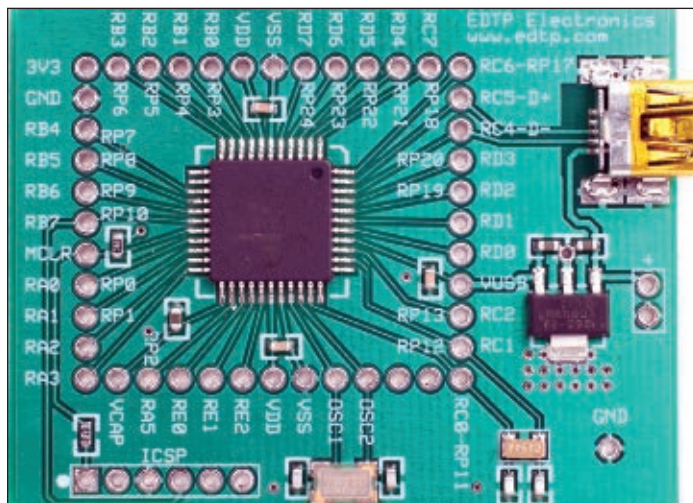
When I got the hots to do this project, I just couldn't wait for a PCB. So, I threw together the microSD card contraption you see in **Photo 3**. Although it seems to be solidly constructed in the photograph, it took a couple of microSD card sockets and a couple of hours to get it all to stick together. That was enough to slap me back into reality.

The trace elements of the microSD interface card are routed in **Screenshot 5**. Pins 1 and 8 are not used in SPI mode. So, to keep this PCB as small as possible, there are no header connections for the unused pins.

Clicking on the microSD interface card components will tell a story that confirms the story being told by **Schematic 1**. A pair of pull-up resistors and a pair of power supply bypass capacitors support the microSD card socket and a tristate buffer. The MC74VHC1GT125DT tristate buffer isolates the microSD card's output which allows other SPI devices to be serviced from the host's SPI portal.

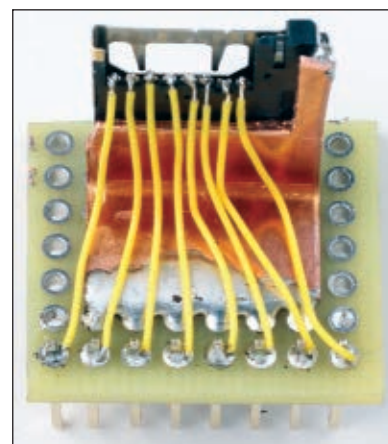
The interface card headers are labeled from the microSD card perspective. SDO — which is Microchip for MISO (Master In Slave Out) — connects to the PIC18F46J50's SDI pin. SDI is Microchip for Master Out Slave In (MOSI) and connects to the PIC18F46J50's SDO pin. The PIC18F46J50 is the SPI master device and provides the clock which emanates from the PIC18F46J50's CLK pin. The microSD card and the tristate buffer outputs are activated with a low-going logic level on the CS pin. The header silkscreen legends are visible in **Screenshot 6**.

■ **PHOTO 4.** This is a bit prettier than the lashup in Photo 3 and much easier to assemble and use.



■ **PHOTO 2.** It's all here except the header pins.

The same ground plane logic we used on the daughterboard is extended to the microSD card interface design. Note the thermal feed through at the GND pin and the top-side ground plane component connections in **Screenshot 7**. The assembled EDTP microSD interface card you see in **Photo 4** measures in at 0.675 x 1.10 inches.

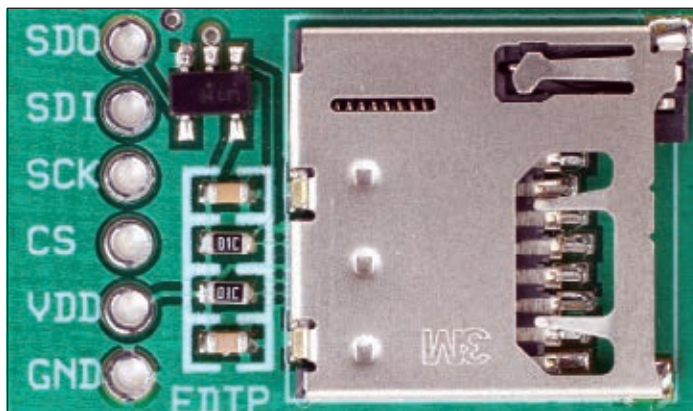


■ **PHOTO 3.** Not only is this ugly, it's hard work.

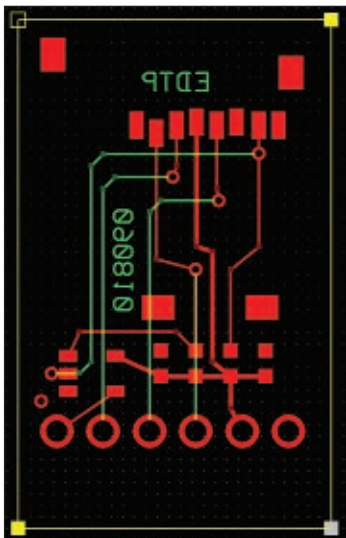
## LOADING THE BOAT

As I mentioned earlier, we're probably going to need an extra board or two to tie everything into a useful design. In that the microSD interface card headers won't directly line up with the PIC18F46J50 daughterboard headers, we're going to need to add a motherboard to provide a means to make the necessary connections.

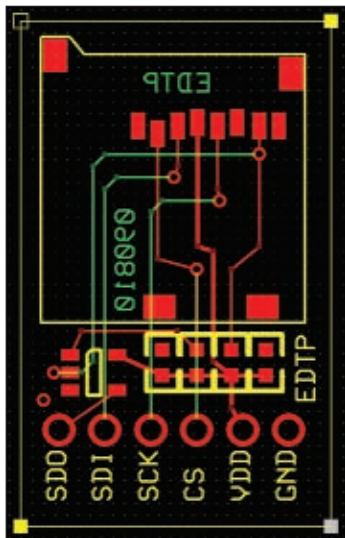
Behold **Photo 5**. Now you know why I kept calling the



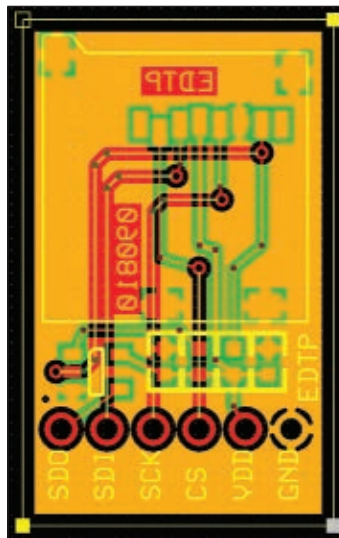




■ **SCREENSHOT 5.** This printed circuit board can be loaded and soldered in the time it took to successfully attach a pair of the wirewrap wires in Photo 3.



■ **SCREENSHOT 6.** This printed circuit board is tiny but every component can be manually mounted with the right soldering tools.



■ **SCREENSHOT 7.** The top and bottom layer ground planes are the glue that holds the circuitry together. If you have doubts about that, try routing the ground connections without the planes.

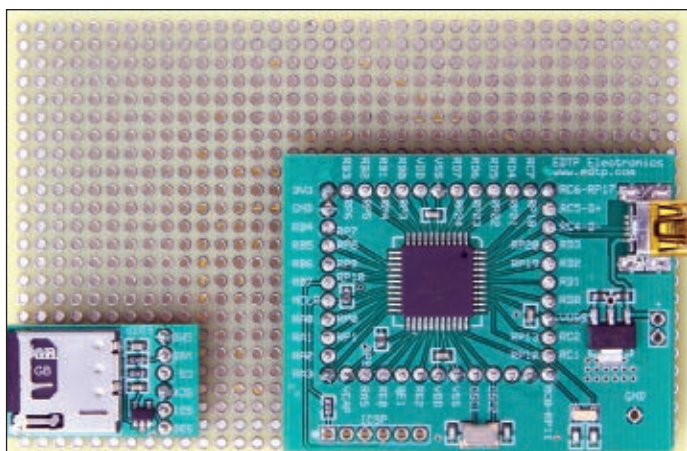
PIC18F46J50 PCB a daughterboard. I decided to forego the use of socket pins and tacked the daughterboard down to a perfboard with double-sided plated-through 0.1 inch centered holes. As you can see, I also nailed the interface card to the double-sided plated-through motherboard.

If you believe **Schematic 1**, we should only have to make six connections to attach the interface card to the PIC18F46J50's SPI portal. You can count'em in **Photo 6**. The absence of header sockets allows the longer portions of the PIC18F46J50 daughterboard header pins to protrude just enough to make excellent wire wrap connections. I'm sure you've counted the connections; my RadioShack wire wrap tool got twisted exactly 12 times.

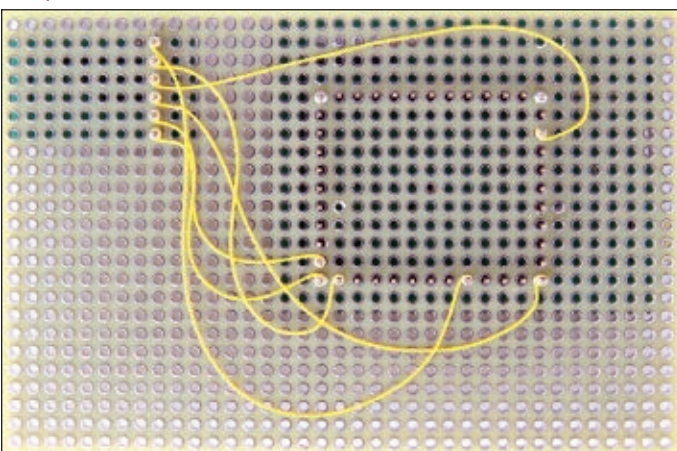
## SETTING SAIL

Call it what you will, but "setting sail" is a seaman's

■ **PHOTO 5.** Everybody is on the boat in this shot. It's time to set sail.



■ **PHOTO 6.** Six wirewrap connections are all it takes to couple the microSD card to the PIC18F46J50.



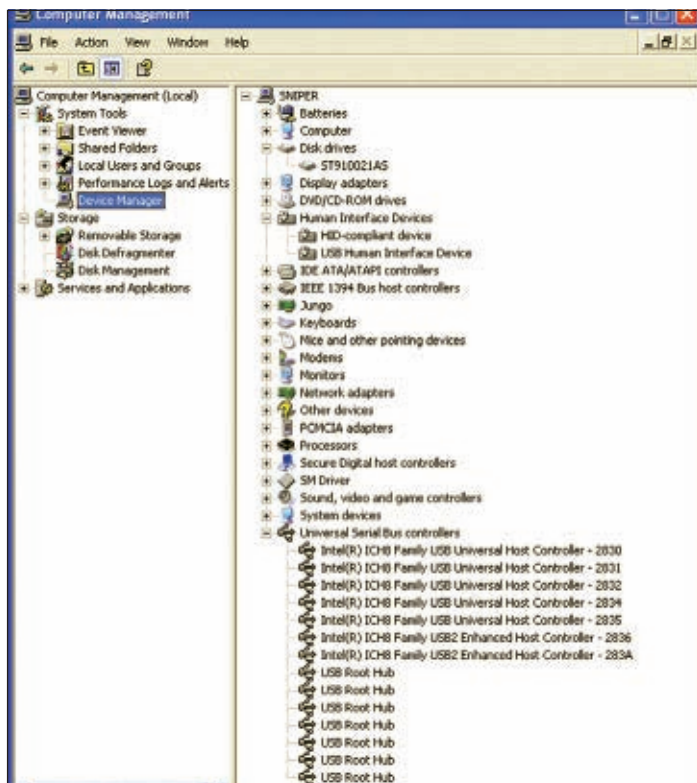
way of saying "smoke test and shakedown cruise." When I plug both ends of a USB cable into their respective port, I stand a chance of releasing the PIC18F46J50's magic smoke and/or testing my laptop's USB emergency stop mechanisms. The

good news is that I can still use our PIC18F46J50 hardware and my laptop to continue with this Design Cycle project.

I intentionally wired the microSD interface card to match the USB/Mass Storage Device demo code that comes packaged with the Microchip Application Libraries. Normally, I would have included some status LEDs and a serial port in the daughterboard design to aid in the debugging phase of the project. In that the idea was to provide you with a universal PIC18F46J50 design, I omitted all of the status LEDs and debugging peripherals from the daughterboard design realizing that they could be mounted on the motherboard and electrically attached to the daughterboard's header pins.

Instead of the standard and methodical debugging methods I normally employ, we're going to perform some Blitzkrieg debugging. The only prerequisite to Blitzkrieg programming is to survey the *HardwareProfile.h* file that accompanies the Application Library demo code you wish to load and execute. If your *HardwareProfile.h* contents accurately reflect your hardware, there's a very good chance that your target hardware will run all or part of the demo application.





■ **SCREENSHOT 8.** Blitzkrieg debugging depends on determining if the changes forced onto the Device Manager are in line with the demo code versus the PIC18F46J50's hardware.

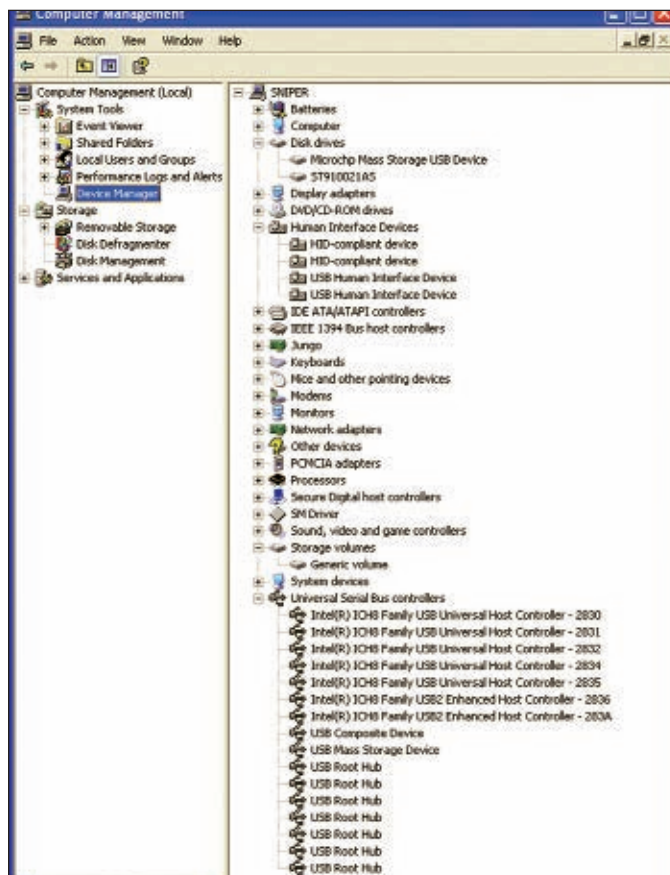
Blitzkrieg debugging does not involve LEDs or serial ports, and depends on the Windows Device Manager to assist in indicating proper operation. **Screenshot 8** is the Device Manager status before attaching the daughterboard to the laptop USB portal. The demo application I've selected installs the PIC18F46J50 daughterboard as a HID-class device with Mass Storage Device capability. A drive letter will be assigned to the daughterboard and any files with the .TXT extensions will be displayed.

The results of our Blitzkrieg debugging mission shown in **Screenshot 9** are favorable. Following the connection of the daughterboard to the laptop's USB portal, a new disk drive entry was posted, an extra set of HID-class devices appeared, a storage volume was added, and a couple of USB bus controllers went into service. The file window in **Screenshot 10** seals the deal. I created the *newfile.TXT* file from my laptop. The *FILE.TXT* file was created by the demo application.

## I CHRISTEN THEE

Now that we have an operational hardware design, let's get rid of that daughterboard moniker. I think Universal Storage Control Module-46J50 or USCM-46J50 is more fitting. Remember that the USCM-46J50 can also support any other PIC microcontrollers with comparable

*Fred Eady can be reached at [fred@edtp.com](mailto:fred@edtp.com).*

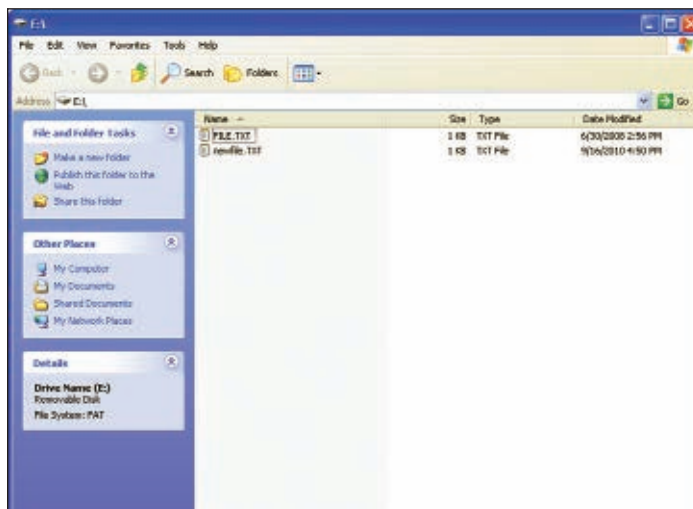


■ **SCREENSHOT 9.** Things are looking up as you can see the additions in the disk drives, HID, storage volumes, and USB controllers areas.

pinouts. The PIC18F4520 (USCM-4520), PIC18LF4620 (USCM-4620), and PIC18F46K20 (USCM-46K20) come to mind immediately. You can also add the PIC18F4XJ53 (USCM-4XJ53) family of USB-enabled parts to the list, as well.

I will make all of the hardware technology we've discussed available to you via the EDTP website. Our microSD card journey has just begun. **NV**

■ **SCREENSHOT 10.** This file window verifies the integrity of the PIC18F46J50 daughterboard and the EDTP microSD interface card. Our microSD card hardware is ready to rock and roll.





# #28 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

Follow along with this series! Joe's book & kits are available at [www.nutsvolts.com](http://www.nutsvolts.com)

## Gettin' A Little Shifty

### Recap

Last month, we finished looking at the AVR memory architecture and wrote a bootloader that lets us upload programs to an AVR without having an external programmer. One of the things we learned in the memory series is that the AVR was designed around Flash EEPROM for program memory. Flash memory is great stuff and you probably have a few billion bytes of it in the form of media cards sitting around in odd places like your cell phone, digital camera, or music player. In addition to the ubiquitous media cards, Atmel has a family of ICs called DataFlash that allow you to use Flash in your circuit designs. Both the media cards and the DataFlash have something in common: they can be written to or read from using the SPI (Serial Peripheral Interface) bus which is probably the simplest serial communications protocol around.

In the next few Workshops, we will progress to using external Flash memory via SPI, but first we will learn about shift registers which lead logically to SPI. The shift registers we are using could be used with AVR hardware SPI, but

we will first write our own software to use our shift registers mainly to show how easy it is and to help understand how these things work. We will look at the 74HC595 eight-bit serial-in-parallel-out and the 74HC597 eight-bit parallel-in-serial-out ICs. [We could also use the 74HC164 74HC165 pair, but the boat left the dock before I realized I had those lying around.] Finally this month, we will apply these chips to create yet another Cylon Eyes display, but this time we will have 16 LEDs to sweep and a full eight-bit DIP switch to allow the user to change the LED patterns. Instead of having to use 24 pins as we would if we did this parallel, we only use four of our AVR I/O pins.

As a bonus, we will do all this on four different development platforms. **Figure 1** shows things wired up with the Butterfly, and **Figures 10, 11, 12, and 13** show the soft SPI pins so that you can use any of these devices: the Butterfly (Workshop 1), the Arduino (Workshop 9), the Breadboarduino (Workshop 21), or the BeAVR40 (Workshop 22) to do the experiments this month.

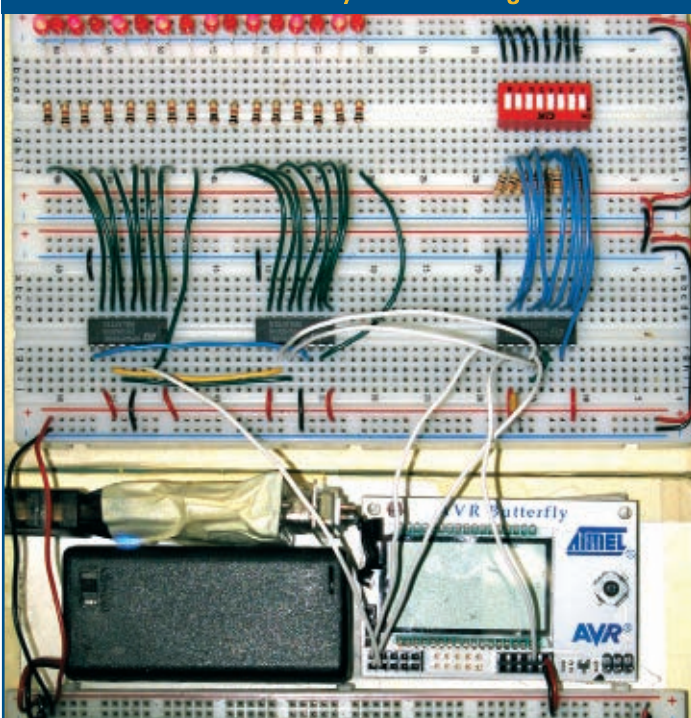
### Shift Registers

If you've had the good fortune of taking a college level course in digital logic, then you already know a lot about shift registers and their basic element: the flip-flop. These circuits are fundamental to the entire digital revolution and if you want to really understand how all your digital electronic servants work, you are going to need to understand these guys. Since our goal at this point is just to use them, I'll leave the gory details to your Google self-education program and glide over the fundamentals.

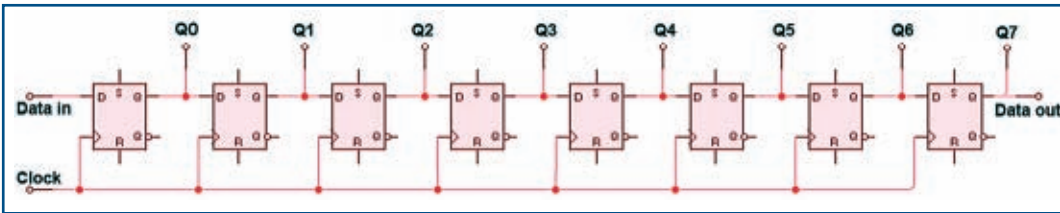
A flip-flop is a circuit that can remember a bit state; either 0 or 1. The most common type of flip-flop is the D or delay flip-flop that records the input bit state on the rising edge and puts that value on the output on the falling edge. Prior to the falling edge, the output is the previous bit state. The rising or falling edge allows us to create a serial shift register with D-type flip-flops arrayed in a sequence such that each input records the prior flip-flop's output on the rising edge, then puts that value on its output on the falling edge.

This is shown in **Figure 2**. [Caveat: Not all flip-flops work exactly the same.] You could do this equally well by having the reverse clock logic if the design calls for it. Each of the flip-flops will also have a clear pin so that you can set them all to 0 at once. When you string eight flip-flops together, then you consider the input of the flip-flop

■ FIGURE 1. Butterfly with Shift Registers.







■ FIGURE 2. Flip-flop Shift Register.

on one end as the serial in pin for the shift register and the output pin on the flip-flop on the other end as the serial data out pin. The Q# pins on each flip-flop hold the full eight-bit data state and can be read or written to for parallel I/O. **Figure 3** shows a parallel byte of data — Q0 to Q7 — being latched into the register, then shifted out one bit at a time for each clock pulse while a new bit is clocked in. Unfortunately for **Figure 3**, I chose the same byte value (0x52) for both the parallel and serial I/O, and though it might have made a bit more sense to illustrate this with two different bytes, hopefully you'll still get the general idea.

## Suggested Resources

If you want further information on shift registers, I suggest you read the Wikipedia sections on flip-flops and shift registers. If you want to REALLY understand these things, get the book *Code* by Charles Petzold. He starts with mechanical relays to recreate digital logic elements that could have been built in the 19th century and shows how the fundamental computer concepts could have been implemented even back then. His approach helps separate the ideas from the implementation which really helps you understand how to make logic machines.

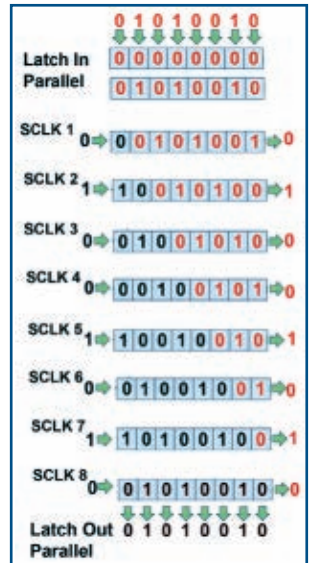
## Serial-In-Parallel-Out Shift Registers — the 74HC595

The '595 — whose pin-out is shown in **Figure 4** — is an eight-bit serial-in-parallel-out shift register IC available in a 16-pin DIP package [[www.nxp.com/documents/data\\_sheet/74HC\\_HCT595.pdf](http://www.nxp.com/documents/data_sheet/74HC_HCT595.pdf)]. The outputs can be in one of three states: VCC, GND, or disconnected (high impedance).

■ FIGURE 4. 74HC595 Pins.

PIN	SYMBOL	DESCRIPTION
1	Q1	parallel data output
2	Q2	parallel data output
3	Q3	parallel data output
4	Q4	parallel data output
5	Q5	parallel data output
6	Q6	parallel data output
7	Q7	parallel data output
8	GND	ground (0 V)
9	Q7'	serial data output
10	MR	master reset (active LOW)
11	SH_CP	shift register clock input
12	ST_CP	storage register clock input
13	OE	output enable (active LOW)
14	DS	serial data input
15	Q0	parallel data output
16	V <sub>CC</sub>	positive supply voltage

You can clear the register by toggling the /MR, and you can shift out data at 100 MHz. There are two registers: one for shifting serial bits and one for buffering the parallel output pins. Each register has its own clock; the serial being clocked by the SH\_CP pin and the parallel by the ST\_CP pin. Both transfer data on the rising edge of the clock.



■ FIGURE 3. Shift Register Concepts.

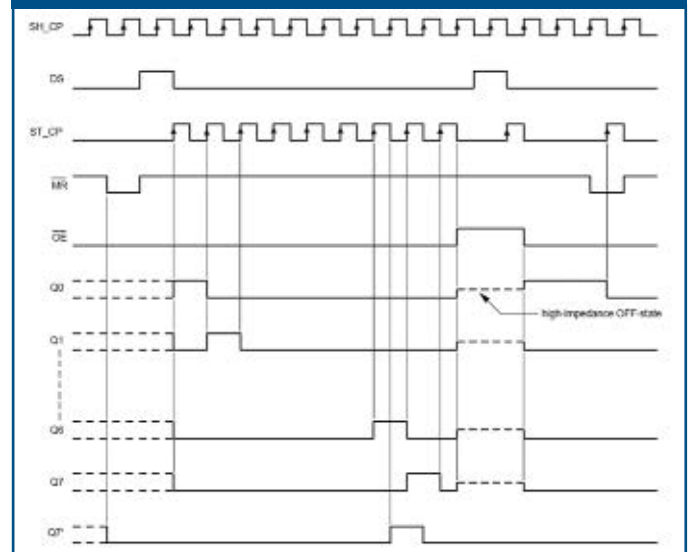
**Figure 5** shows how bits are clocked into this device.

We use the 595 by presenting a bit of data on the serial data input pin 14 (DS) and then toggling the shift register clock input pin 11 (SH\_CP) as shown in **Figure 5**. We do this for the eight bits that we want to shift into the register, then we toggle the shift register clock input pin 12 (ST\_CP) to cause the 595 to move the data from the serial shift register to the parallel output register. We can hook these in series so that the serial data output line pin 9 is connected to the next 595's serial data input pin 14 (DS). The only difference is that we shift in 16 bits instead of eight as with the single 595.

## Parallel-In-Serial-Out Shift Registers — the 74HC597

The 74HC597 (whose pin-outs are shown in **Figure 6**)

■ FIGURE 5. 74HC595 Timing Diagram.





PIN	SYMBOL	DESCRIPTION
1	D1	parallel data input
2	D2	parallel data input
3	D3	parallel data input
4	D4	parallel data input
5	D5	parallel data input
6	D6	parallel data input
7	D7	parallel data input
8	GND	ground (0 V)
9	Q	serial data output
10	MR	master reset (active LOW)
11	SH_CP	shift register clock input
12	ST_CP	storage register clock input
13	PL	parallel load (active LOW)
14	DS	serial data input
15	D0	parallel data output
16	V <sub>CC</sub>	positive supply voltage

■ FIGURE 6. 74HC597 Pins.

SPI, I've named the pin signals with their SPI equivalents.

In our software, we need to do several things to send out the 16 bits of serial data and have them show up on the two 595 outputs. First, we set the /SS (Slave Select) to 1 so that the bits will not show on the parallel output while they are being shifted into the devices (this locks the old data on the output until all the new data is input). Next, we present each of the 16 bits in sequence on the MOSI (Master Out Slave In) pin, followed by toggling the SCLK (Serial CLock) pin that tells the 595 to shift that bit into the serial register. Finally, after all 16 bits are shifted in, we set the /SS low which causes the serial bits in the serial shift register to be transferred to the parallel output register. The following code snippet shows how to turn on every other LED:

```
// Set alternate LEDs on off
// 0x5555 HEX <> 0101010101010101 binary
uint16_t myVar = 0x5555;

// Clear slave select
// so data won't show while shifting
clear_ss();

// output 16 bits to the 595
for (i=0; i<=15; i++)
{
    // Put bit on mosi_pin
    if (is_bit_set(myVar, i))
        set_mosi_bit();
    else
        clear_mosi_bit();

    // Toggle the clock to output it
    toggle_clock();
}

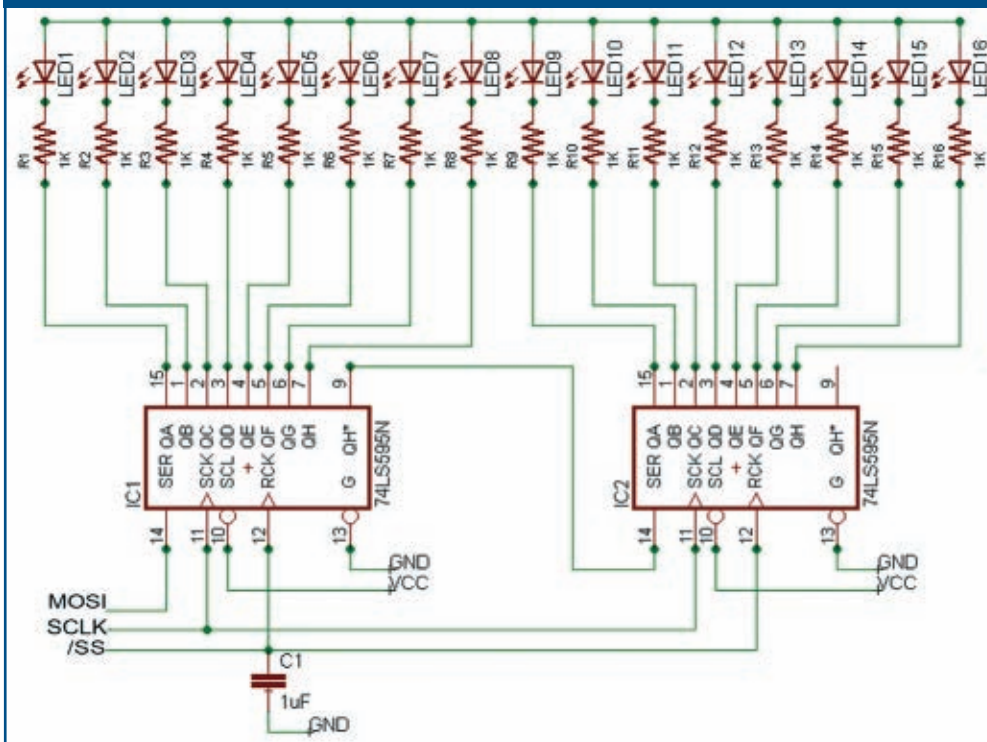
// Set slave select to transfer data
// from serial to parallel registers
set_ss();
```

is sort of the sister chip to the 595 in that it reverses the process. It adds one non-SPI control line that is required to load the data from the parallel pins to the shift register before clocking the data out. For our purposes, we hook this line to the ST\_CP line so that we latch bits and load bytes in one operation which doesn't seem to hurt anything [[www.nxp.com/documents/data\\_sheet/74HC\\_HCT597\\_CNV.pdf](http://www.nxp.com/documents/data_sheet/74HC_HCT597_CNV.pdf)].

## Using the 74HC595 — Control 16 LEDs

Figure 1 shows a bit of a rat's nest of wires on breadboards. The two ICs on the left are 595s and are used to control the 16 LEDs. The schematic for this is shown in Figure 7, but please note that this doesn't show the IC VCC and GND connections with pins 14 and 8, respectively. Since our goal is to get some preliminaries on

■ FIGURE 7. Serial-In-Parallel-Out Schematic.



Since our purpose at this point is to get the 595 working, we'll defer looking at the SPI macros in the code snippet (hey are in the source code).

## Using the 74HC597 — Read an eight-bit DIP Switch

We will test this IC using the circuit shown in Figure 8. We use the 597 by first toggling the storage register clock input pin 12 (ST\_CP) to shift the parallel port input pin states (D0-D7) to the parallel register. Next, we toggle the parallel load line pin 13 (/PL) which causes the 597 to move the data present in the parallel input register to the serial shift register. Finally, we toggle the shift register clock input pin 11 (SH\_CP) eight times to shift the



bits out on the serial data output pin 9 (Q) which we monitor with our MISO (Master In Slave Out) pin. We can see this process in action in the following code snippet:

Code Snippet:

```
uint8_t my_data_in = 0;

// Clear slave select
// so data won't show while
// shifting
clear_ss();

// load 8 bits from the 597 into
// my_data_in byte
for (i=7; i>=0; i-)
{
    // Toggle the clock to get the
    // next bit
    toggle_clock();

    // If data pin = 1 set it
    // in my_data otherwise
    // do nothing since my_data_in is
    // initialized to 0
    if (get_miso_bit())
        my_data_in |= (1 << i);
        uart_send_bit(1);
    }
    else
    {
        uart_send_bit(0);
    }
}

// Set slave select to transfer data
// from serial to parallel registers
set_ss();
```

This snippet is part of Shift\_Register.c code that you can get in the Workshop28.zip from *Nuts & Volts*. When you set the DIP switch to 0xAA (binary 10101010), run the program while communicating with Brays terminal, and move the lowest bit from 0 to 1 you get the output shown in **Figure 9**.

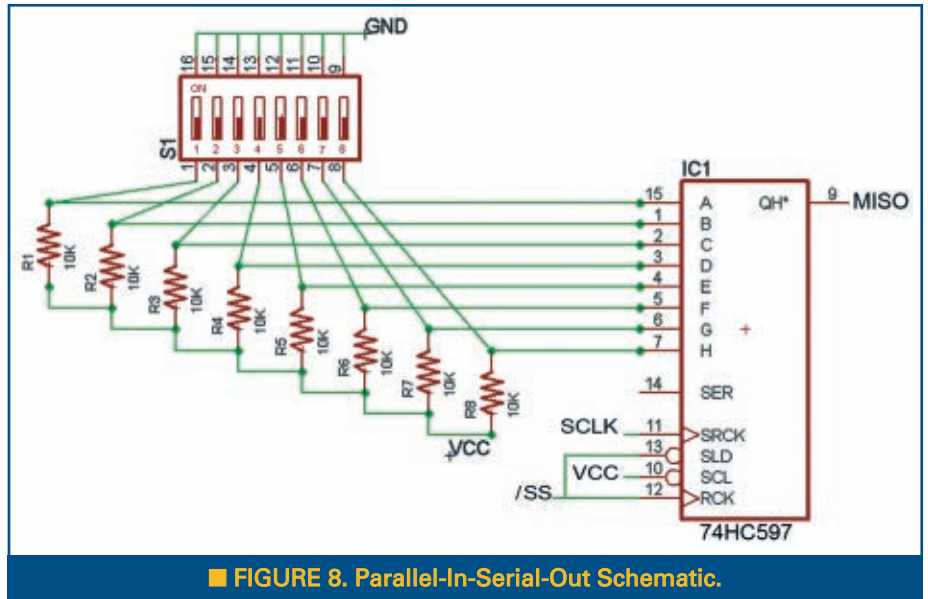
## Software SPI Pins

SPI uses four pins: MOSI, MISO, SCLK, and /SS. For us to use these in software, we must designate specific pins from specific ports and then we must set them up for data direction (input or output). While any pins common to all the boards we are writing our code for would be okay to use, we will define the following:

```
#define mosi_port PORTB
#define mosi_port_pin PORTB2
#define mosi_ddr DDRB
#define mosi_port_pins PINB

#define miso_port PORTB
#define miso_port_pin PORTB1
#define miso_ddr DDRB
#define miso_port_pins PINB

#define sclk_port PORTD
#define sclk_port_pin PORTD7
#define sclk_ddr DDRD
```



■ FIGURE 8. Parallel-In-Serial-Out Schematic.

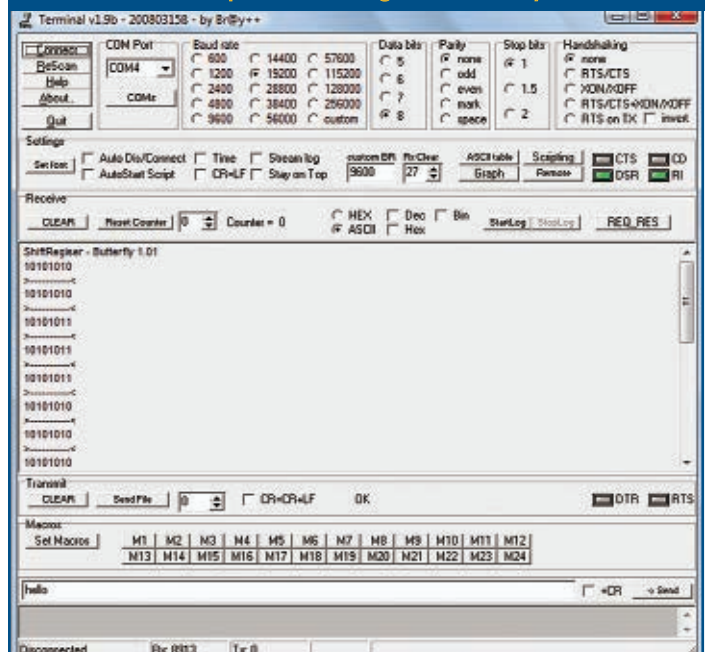
```
#define ss_port PORTB
#define ss_port_pin PORTB0
#define ss_ddr DDRB
```

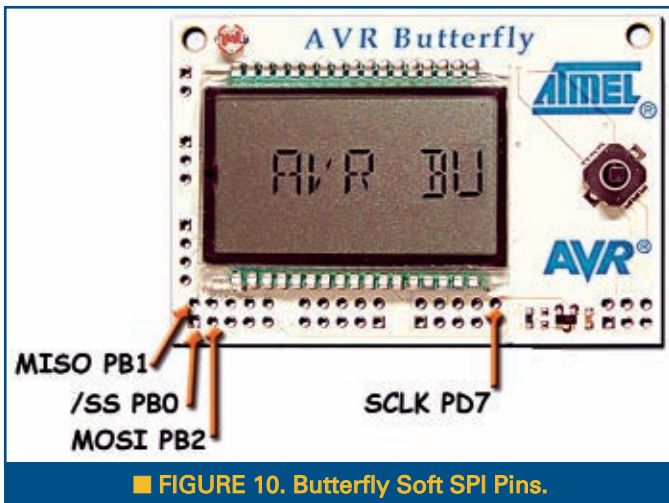
We then set the data direction as follows:

```
void setup_pins()
{
    // Initialize MISO as input
    // set DDR pin register to 0
    miso_ddr &= ~(1<<miso_port_pin);

    // Initialize MOSI, SCLK, AND /SS as
    outputs
    // set DDR pin registers to 1
    mosi_ddr |= (1<<mosi_port_pin);
    sclk_ddr |= (1<<sclk_port_pin);
    ss_ddr |= (1<<ss_port_pin);
}
```

■ FIGURE 9. Output of ShiftRegister.C in Brays Terminal.



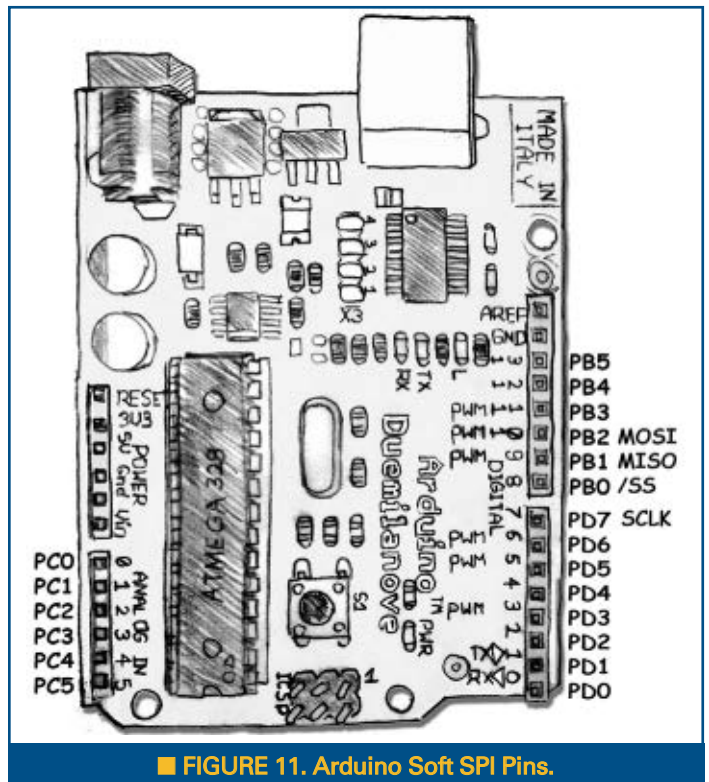
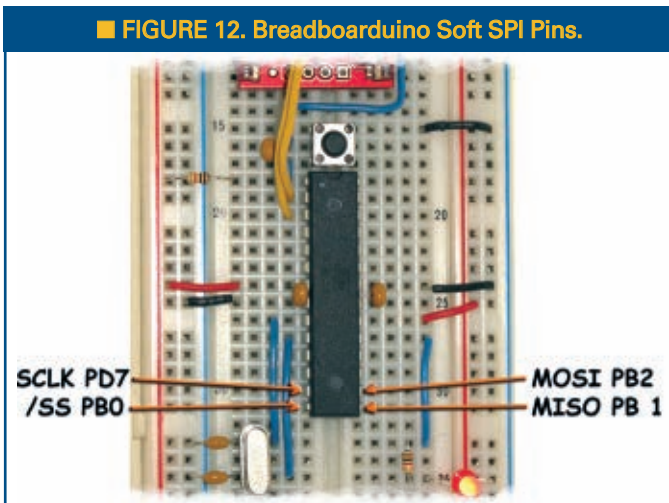


If the way I'm setting or clearing bits isn't clear from earlier Workshops, then I highly recommend that you refer to a tutorial: [TUT] [C] Bit manipulation (a.k.a., "Programming 101") located at: [www.avrfreaks.net/index.php?name=PNphpBB2&file=viewtopic&t=37871](http://www.avrfreaks.net/index.php?name=PNphpBB2&file=viewtopic&t=37871). This will also help when you look at the source code.

I'll admit to getting confused trying to remember which pin represented which signal so that I could properly connect my software SPI signals from each of the platforms to the 595 and 597. To help with this, you can refer to **Figures 10, 11, 12, and 13**, which show the Butterfly, Arduino, Breadboarduino, and BeAVR40, respectively, with the soft SPI pins labeled.

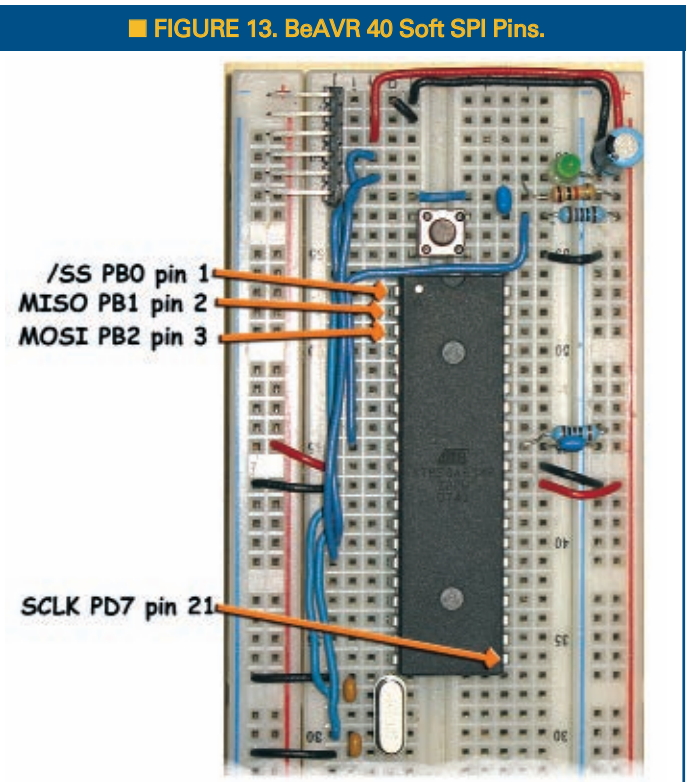
## Yet Another Cylon Eyes Project

**Figure 1** shows the circuit being controlled by an AVR Butterfly, but the source code is written to run on any of the devices shown in **Figures 10, 11, 12, or 13**. The full program has a bunch of sweep patterns and speeds selectable from the DIP switch, but here we'll look at an excerpt snippet that shows how the plain old Cylon Eye sweep is run. We first create an array of values that will



sweep the lit LED from right to left and then we run that array forward and backward as shown:

```
/*
To create a 16 LED Cylon Eye effect
output this array 0 to 15 then 15 to 0
0000 0000 0000 0001 == 0x0001
```





```

0000 0000 0000 0010 == 0x0002
0000 0000 0000 0100 == 0x0004
0000 0000 0000 1000 == 0x0008
0000 0000 0001 0000 == 0x0010
0000 0000 0010 0000 == 0x0020
0000 0000 0100 0000 == 0x0040
0000 0000 1000 0000 == 0x0080
0000 0001 0000 0000 == 0x0100
0000 0010 0000 0000 == 0x0200
0000 0100 0000 0000 == 0x0400
0000 1000 0000 0000 == 0x0800
0001 0000 0000 0000 == 0x1000
0010 0000 0000 0000 == 0x2000
0100 0000 0000 0000 == 0x4000
1000 0000 0000 0000 == 0x8000
*/

```

```

uint8_t i = 0;
uint16_t ce[] = { 0x0001,
0x0002, 0x0004, 0x0008, 0x0010,
0x0020, 0x0040, 0x0080, 0x0100,
0x0200, 0x0400, 0x0800, 0x1000,
0x2000, 0x4000, 0x8000 };

```

```

// Sweep right to left
for (j=0; j<=15; j++)
{
// Clear slave select
// so data won't show while
shifting
clear_ss();
// output 16 bits to the 595
for (i=0; i<=15; i++)
{
// Put bit on mosi_pin
if(is_bit_set(ce[j], i)
set_mosi_bit();
else
clear_mosi_bit()
}
}

```

```

// Toggle the clock to output it
toggle_clock();
}
// Set slave select to transfer
data
// from serial to parallel
registers
set_ss();
// Wait a while
delay_ms(100);
}

```

To sweep the LED back, just run the 'for' loop backwards as shown in the source code.

## Last Shift

Well, shift registers are a pretty cool way to save microcontroller pins, but in case you've forgotten, all this is in preparation so we can learn hardware SPI and use it to read external Flash memory. We'll continue in that direction next month. In the meantime, if you want to get a leg up on this you can purchase my book *C Programming for Microcontrollers* along with a projects kit from *Nuts & Volts*. If this seemed a bit dense, then you might want to try my book *An Arduino Workshop*, also available from *Nuts & Volts*. **NV**



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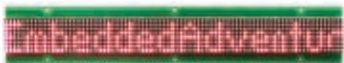
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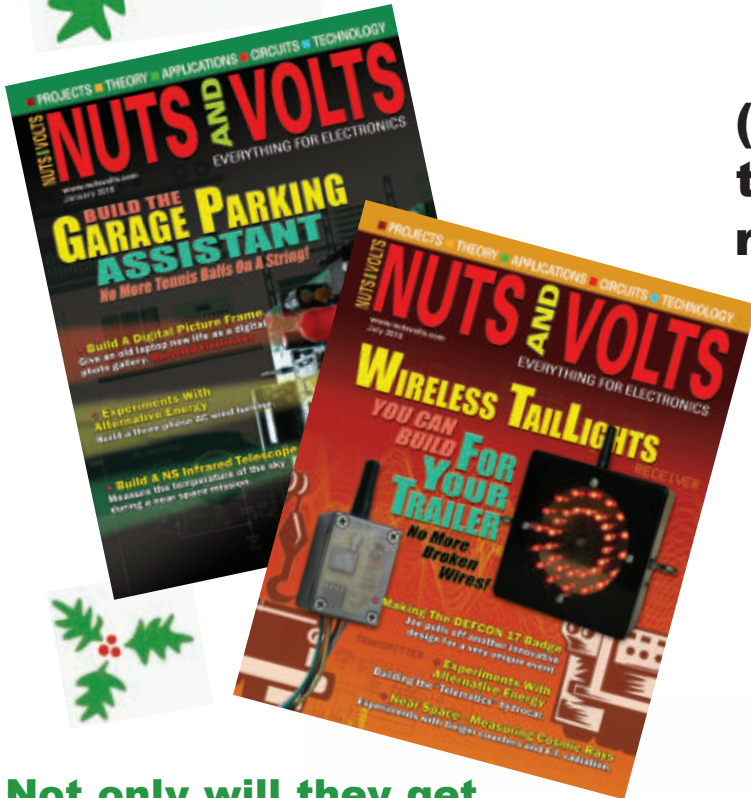
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■ BY L. PAUL VERHAGE

# THE CANON HACKER DEVELOPMENT KIT - PART 2

Last time, this column introduced CHDK and how to load it on a camera's SD card. Locking the SD card makes it bootable on a Canon camera and that allows you to write simple scripts that automate features of Canons that aren't otherwise available. This month's column discusses the syntax of the uBasic scripting language so you can begin writing your own scripts. The next article will cover when I gave a NearSys BalloonSat flight computer control of a Canon camera running a remote script.

There is no editor for uBasic per say, although it would make a great tool if it could syntax check scripts before loading them into your Canon (hint, hint). So, if there's no uBasic editor, what program does one use to create a script? Most people probably use Notepad because uBASIC scripts are text files without formatting commands.

## SOME CHDK SYNTAX

One way to teach syntax is to explain with examples. So, let's look at the two scripts I've worked with so far. I selected these scripts because they are appropriate for my near space missions. The first example allows my PowerShot A550 to take pictures when the flight computer commands it to. I would use this script in conjunction with a sun sensor. When the near spacecraft rotates to the proper sun angle, the flight computer would instruct the camera to take a picture. Controlling the camera based on sun angle prevents some of the wasted images that occur when the camera shoots an image while it is pointed directly at or directly away from the sun. A script like this would also allow the flight computer to orient the camera with a servo before recording an image. This script uses the camera's USB port like a cable release:

```
rem NearSys USB Remote
rem Enable Remote operation in camera's menu
@title Remote Button
:loop
wait_click 1
is_key k "remote"
if k=1 then shoot
```

```
goto "loop"
end
```

Here's an explanation of the syntax in this short script.

### REM

REM is short for remark. uBasic ignores remarks; they're placed in the script just for us humans.

### @title Remote Button

@title indicates the title or name of the script. This is the title that shows up on the camera's LCD screen once you start the script.

### : loop (colon loop)

The colon signifies a label. Labels are locations you can send programs to using **goto** and **gosub**.

### wait\_click n

**wait\_click** is a command that tells the camera to wait for any button to be pushed. It's not required that a number appear after the **wait\_click**. However, if there is a number, then the number is a timeout that the script waits in milliseconds. Either after a button is pushed or when the timeout occurs, uBASIC goes to the next line in the script. Timeouts can be life savers if something is wrong with the script or the camera hangs.

### is\_key k "remote"

The **is\_key k "remote"** statement asks if the last button pushed was the one called **remote**. If true, then the variable **k** is set to 1 (true). If not true, then the variable **k**



is set to 0 (false). Any button name can appear in quotes after the **is\_key** command. If the command is written **is\_key m "up"**, then the variable **m** is set to one only if the last key pressed was the camera's **up** key.

### if k=1 then shoot

This is the standard **if-then** statement. If the variable **k** was set to 1 (because the previous line of script set it to one when the last button pressed was the **remote** button), then the command **shoot** is executed. If variable **k** was not the last button pressed, then the **shoot** command does not take place. Associated with the **if-then** command is **else**. The **else** command indicates what the script is suppose to do if the conditional statement is not true. So, for example:

```
if k=1 then shoot else goto no_go
```

Notice that a command follows the **if-then-else** statement. More than one command can follow an **if-then-else**. That makes the following script record an image, increment a counter, and display the value of the counter when a condition is valid (that is, **k=1**). When the condition is invalid, it increments a different counter and displays its value.

```
if k=1 then
shoot
n=n+1
print "image" n
else
k=k+1
print "fail" k
endif
```

### shoot

The **shoot** command clicks the camera's shutter. In other words, the camera takes a picture. The **shoot** command runs the camera through the focus process before recording an image.

### goto "loop"

Whether the camera took a picture or not, the next line of script sends uBASIC to the label named **loop**. The label begins with a colon in the script, but is referenced by a **goto** or **gosub** command wrapped in quote marks.

### end

Just like other versions of BASIC, **end** marks the last line of the script. If uBASIC comes across this line, all execution halts. The second script we'll look at is a simple intervalometer. This script is appropriate for a BalloonSat that is not carrying a programmable flight computer. In the old days (circa 2003!), students would build intervalometers with 555 timer ICs. Now they can fly a Canon camera and add this simple script to its SD card.

```
rem Modified by NearSys 3 Sept 2010
@title Intervalometer
:interval
for n=1 to 200
sleep 10000
shoot
next n
end
```

There are two new commands in this script.

```
for n=1 to 200
:
:
:
next n
```

The **for-next** command is for simple loop control. In this example, the commands between the **for** and the **next** are repeated 200 times (in the example above, the camera will take 200 photographs before stopping). The variable controlling the looping in this example is named **n**. Therefore, the end of the loop must reference this variable. Using different variables permits scripts to nest **for-next** loops. By the way, variables in uBASIC are any lower case letter (**a** to **z**) and can hold any number between -999,999 and +999,999. There's no need to define variables in uBASIC scripts.

### sleep 10000

The **sleep** command pauses the execution of the script in units of milliseconds. In this example, the camera pauses for 10 seconds every time it records an image.

## OTHER COMMANDS

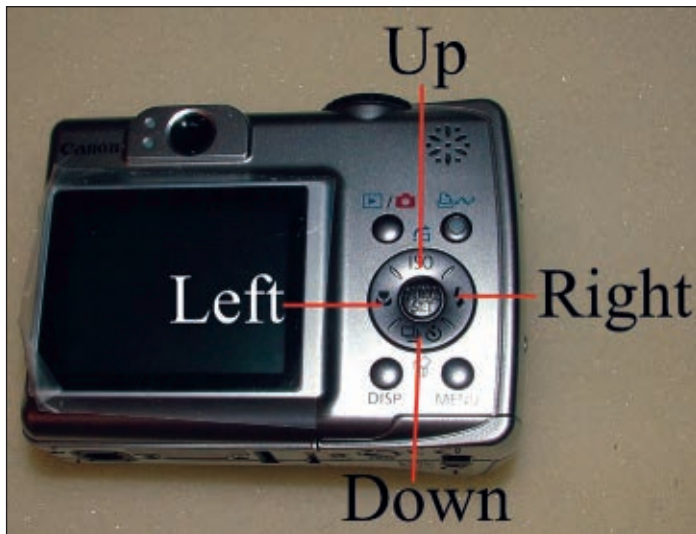
uBASIC permits you to control all the functions of your Canon camera like you were pressing its buttons. Many readers have scrolled and clicked buttons on their digital cameras before. These buttons have names that can be referenced in a uBASIC script with the **click** command. So, rather than setting up your camera by clicking a series of buttons, you can load a script to do it for you. Here's how the syntax works:

```
click "up"
```

This command momentarily presses the **up** button. The **up** button is the top button in the scroll button on many cameras. The other three in the scroll button are **down**, **left**, and **right**. The name of the button follows the command **click** and is wrapped in quote marks. Now **click** only presses the button for a moment. If a button must be held down for other options to be selected, then use the **press** command. So, for example, I might press and hold the menu button so the up button can activate a new feature that isn't available while the menu button is not held down. The syntax for the **click**, **press**, and **release** commands are all the same, with the name of the button wrapped in quote marks after the command. The script for pressing and holding the menu button while clicking the up button to bring up an option, and then clicking the right button to select it would look like this:

```
press "menu"
click "up"
click "right"
release "menu"
```

A few other buttons demonstrate the power of using CHDK.



■ Just a few of the camera's buttons you can control with CHDK. Scripts allow you to automate the pressing of the buttons you would normally use to set up your camera.

#### set\_zoom n

The `set_zoom` command changes the camera's zoom setting. Cameras zoom in steps (not in analog like manual cameras) and the amount of zoom is specified by the variable `n`. Depending on the camera, it can have 9, 15, or 129 zoom steps. Related to setting zoom in absolute terms, the zoom can be adjusted from its current setting with the following command:

```
set_zoom_rel x
```

This is a relative setting where `x` can be a positive or negative number. The value of `x` is added to the current zoom setting to move it in or out. A camera's desired zoom setting can be dependent on the camera's current zoom setting. To get the current zoom setting, use the following command:

```
get_zoom x
```

The current setting of the camera's zoom is loaded into the variable `x`. The value in the variable `x` can be evaluated and acted upon with an **if-then** statement. Related to the **shoot** command is the **shoot\_half** command. This command is equivalent to pressing the shutter button only half way. Doing so refocuses the camera and is necessary after zooming the lens since cameras don't refocus themselves after zooming. For a near space mission, I might use a camera at a minimum zoom setting to get a context picture of the ground and then take a second picture at a higher zoom. Cool, isn't it?

#### print

The **print** command displays text on the camera's LCD screen. For example, a script would use **print** "picture" `n` to display the word "picture" followed by the number stored in variable `n`. The following script snip takes a picture, increments the number of pictures taken, and displays the results on the camera's LCD screen. It's useful for determining how successful a near space mission was upon recovery, but before you get a chance to extract the SD card.




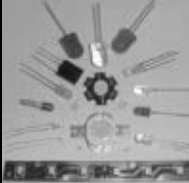
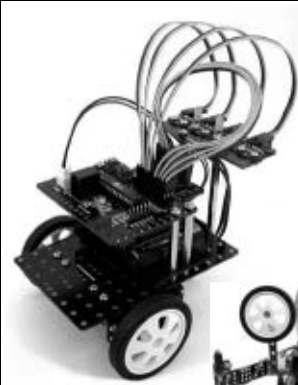
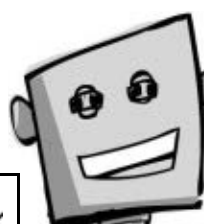
```
shoot
n=n+1
print "picture" n
```

#### shut\_down

This command powers off the camera. It's used at the end of a camera's sequence of actions to shut the camera off.

Scripts can get pretty complex. For example, a camera can monitor a part of its field of view and when a change occurs within that field, the camera can take a picture. This allows people to use Canons to record wild life and

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lightning. One limit in CHDK is the size of the script. No script can have more than 8,196 (8K) characters. Help files about CHDK and uBASIC syntax can be found at <http://chdk.wikia.com/wiki/CHDK>. After writing a script in Notepad, follow these steps to save it to an SD card:

- Click **File**.
- Click the **Save in** window.
- In the **Save in** window, locate your SD card and go to CHDK and then SCRIPTS.
- In the **Save as type:** window, select All Files.
- In the **File name:** window, type the file's name and end with a .bas (like nearspace.bas).
- Click the **Save** button.

Be sure you unlock the SD card before inserting it into your PC and lock it before reinserting it into your Canon.

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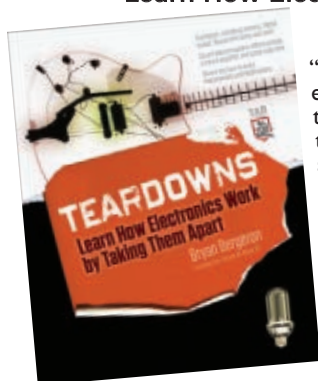


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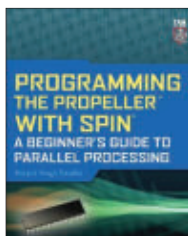
*Master and Command C for PIC MCU, Volume 1* aims to help readers get the most out of the Custom Computer Services (CCS) C compiler for PIC microcontrollers. The author describes some basic compiler operations that will help programmers — particularly those new to the craft — create solid code that lends itself to easy debugging and testing. As Eady notes in his preface, a single built-in CCS compiler call — such as `output_bit` — can serve as a basic aid to let programmers know about the "health" of their PIC code.



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Programming the Propeller  
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by Harprit Singh Sandhu

*Programming the Propeller with Spin: A Beginner's Guide to Parallel Processing* walks you through the essential skills you need to build and control devices using the Propeller chip and its parallel processing environment. Find out how to use each of the identical 32-bit processors — known as cogs — and make the eight cogs effectively interact with each other. The book covers Propeller hardware and software setup, memory, and the Spin language.



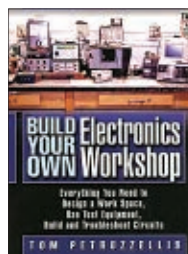
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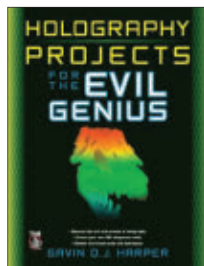


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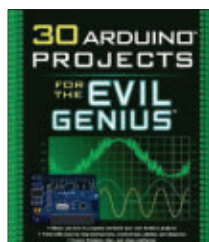
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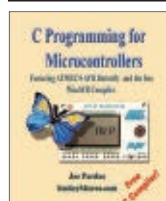
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### The Beginner's Guide Combo!



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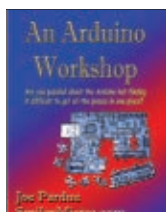
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## PROJECTS

### Piezoelectric Film Speaker Kit



**NEW!**

As seen in this month's issue, here is a great project to amaze your friends and to demonstrate a unique way of producing sound.

Kit contains one piece of piezoelectric film, speaker film stand, PCB, components, audio input cable, and construction manual. All you'll need to add is a battery and a sound source.

For more info, please visit our website.

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### Xmas Tree Kit



**Includes an article reprint.**

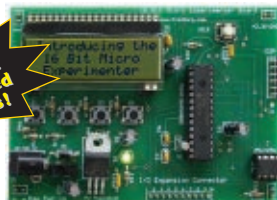
The microprocessor-controlled Xmas Tree comes with 8 preprogrammed light display sequences. All you need is a soldering iron and a couple of batteries, and you'll be ready to show off your electronic tree!

**To see a demo video, please visit [www.nutsvolts.com](http://www.nutsvolts.com)**

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### 16-Bit Micro Experimenter Board

**Now available! Assembled boards!**



Ready to move on from 8-bit to 16-bit microcontrollers? Well, you're in luck! In the December 2009 *Nuts & Volts* issue, you're introduced to "the 16-Bit Micro Experimenter."

The kit comes with a CD-ROM that contains details on assembly, operation, as well as an assortment of ready-made applications. New applications will be added in upcoming months.

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### Garage Door Alarm PCB & Chips

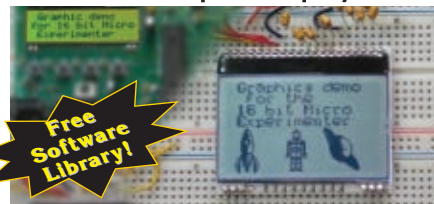


**As seen in the November 2010 issue.**  
**Is Your Garage Door Open?**

This project uses the latest in wireless technology, and is a fun and easy project to build. We provide the difficult parts: the transmitter and receiver PCBs with their matching programmed MCUs. The other components can be found at your favorite parts house.

**Includes an article reprint.**  
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### 128x64 Graphic Display Kit



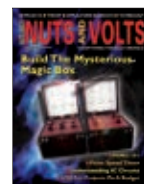
**Free Software Library!**

**New application for the 16-Bit Micro Experimenter**

LCD displays ... they have been around for quite some time, but what if you could have both characters, as well as graphic displays at the same time? With this kit, we will show you how easy and inexpensive this technology can be using the 16-Bit Micro Experimenter.

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### Magic Box Kit



**As seen on the April 2007 cover**

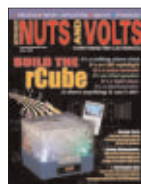
This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. This clever trick has the observer remove one of six pawns while you are out of the room and upon re-entering you indicate the missing pawn without ever opening the box.

**Includes an article reprint.**  
**Subscriber's Price \$39.95**  
**Non-Subscriber's Price \$45.95**

### rCube Talking Alarm Clock Kit



**As seen on the May 2009 cover**



Available in blue, black, red, and green. All components are pre-cut and pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

**Subscriber's Price \$49.95**  
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### Nixie Tube Clock Kit



**Cherry Wood Clock Case**



**October 2006**

Nixie tube clocks fuse the spirit, drama, and eerie beauty of cold war technology with modern inner works to create uncommon handcrafted timepieces.

**Now with optional case choices!**  
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**Kit includes article reprint, complete instructions, and parts list**

**Subscriber's Price \$146.95**  
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### NixieNeon Clock Kit



**Now With New Code!**

Using Neon and Nixie bulbs, this clock displays the precision movement of time and is programmable to display "Time Chaos" at different intervals. The NixieNeon Clock then resets itself to the correct time in an eye-catching ballet of luminosity. The PCB is 7.25"x 7.25" and consists of over 400 components.

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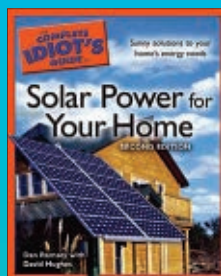
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### Run Your Diesel Vehicle on Biofuels A Do-It-Yourself Manual by Jon Starbuck, Gavin D J Harper

CONVERT TO BIODIESEL FOR A MORE ENVIRONMENTALLY FRIENDLY RIDE! *Run Your Diesel Vehicle on Biofuels* has everything you need to make the switch from expensive, environment-damaging carbon fuel to cheap (and, in many cases, free), clean fuel for your vehicle. Practical and decidedly apolitical, this unique guide focuses on technical details, parts, and instructions.

**\$24.95**



### 50 Green Projects for the Evil Genius by Jamil Shariff

Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life!

**\$24.95**

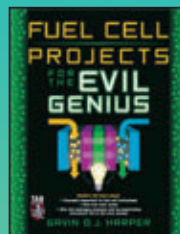


### Fuel Cell Projects for the Evil Genius by Gavin D J Harper

FUEL YOUR EVIL URGES WHILE YOU BUILD GREEN ENERGY PROJECTS!

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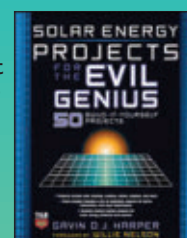
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### Solar Energy Projects for the Evil Genius by Gavin D J Harper

Let the sun shine on your evil side — and have a wicked amount of fun on your way to becoming a solar energy master! In *Solar Energy Projects for the Evil Genius*, high-tech guru Gavin Harper gives you everything you need to build more than 30 thrilling solar energy projects. You'll find complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin.

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### B3-Phase Wind Turbine Kit



The Whirlybird Three-Phase Wind Turbine Kit is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 6 and 7, he teaches you how to produce the most electricity utilizing the wind. For kit details, please visit our website.

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### Hydrocar Kit



The Hydrocar is used in a couple of great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 10 and 11, he teaches you the operation of the Polymer Electrolyte Membrane "reversible" fuel cell. For kit details and a demo video, please visit our website.

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### Windpitch Kit



The WindPitch Wind Turbine Kit is a miniature real-working wind turbine and is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 8 and 9, he teaches you how to produce the most power by evaluating the pitch (setting angle) of the profiled blades. For kit details, please visit our website.

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# FUNDAMENTALS FOR THE BEGINNER

A kit for these experiments can be purchased from the *Nuts & Volts* Webstore at [www.nutsvolts.com](http://www.nutsvolts.com) or call us at 800-783-4624.

## HOW A PNP TRANSISTOR WORKS

In this experiment, we will build a simple circuit to observe a PNP transistor serving as a current amplifier.

### 1. Build the Circuit.

Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

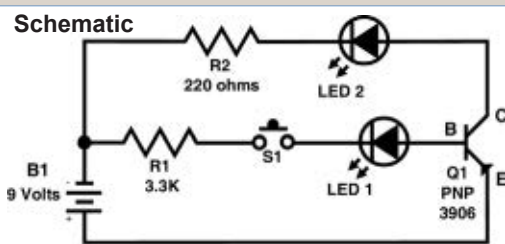
### 2. Do the Experiment.

**Theory:** In this circuit, when you press switch S1, the electrons will flow from the negative of the battery through the 3,300 ohm resistor, Switch S1, LED1, the Base-Emitter junction of Q1, and then back to the positive of the battery. At the same time, electrons flow through R2 (the 220 ohm resistor), LED 2, the Collector-Emitter junction of Q1, and back to the positive of the battery. There must be Base-Emitter current before any current will flow in the Collector-Emitter circuit. This act of a smaller current controlling a larger current is referred to as amplification.

Within limits, as we increase the current in the Base-Emitter circuit, it will increase the current flowing in the Collector-Emitter circuit. By adjusting the value of R1, you can use an ammeter to observe the change in currents.

**Procedure:** Connect a nine-volt battery to the battery snap and press the pushbutton switch to cause current to flow. Both LEDs should light up. When you release the pushbutton switch, both LEDs should turn off.

Schematic



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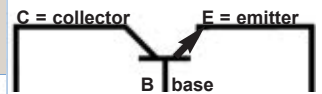
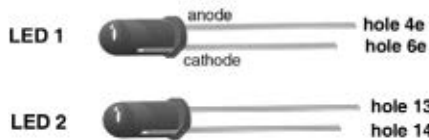
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### LIGHT EMITTING DIODE (LED)



### TRANSISTOR



### PUSHBUTTON

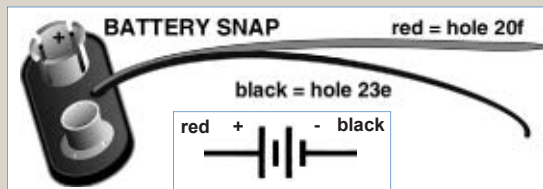


### RESISTORS

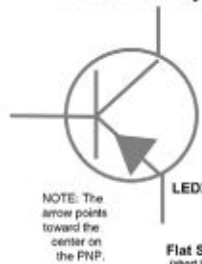


### WIRES

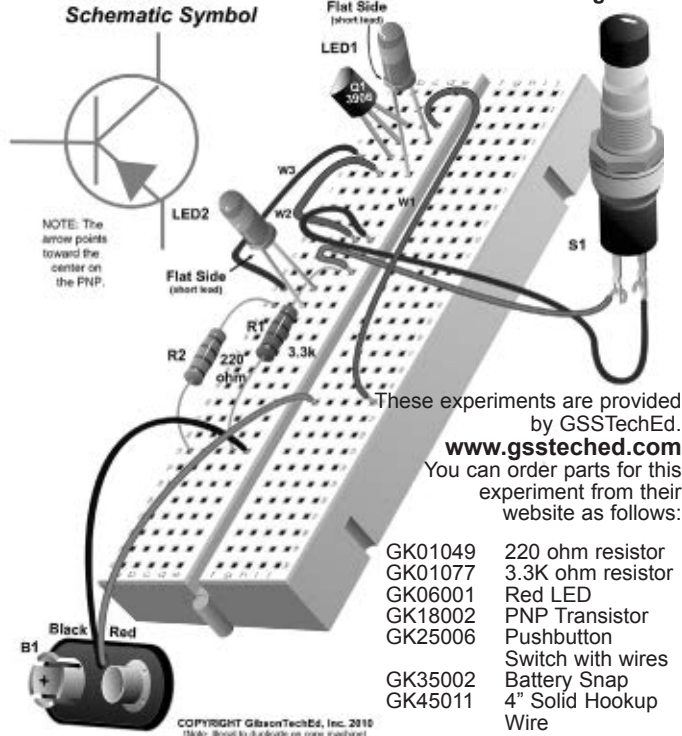
W1 = 3e and 20j  
W2 = 6c and 10d  
W3 = 5a and 13a



### PNP Transistor Schematic Symbol



### Pictorial Diagram



GK01049 220 ohm resistor  
GK01077 3.3K ohm resistor  
GK06001 Red LED  
GK18002 PNP Transistor  
GK25006 Pushbutton  
GK35002 Switch with wires  
GK45011 Battery Snap  
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# READER-TO-READER TECHFORUM

## >>> QUESTIONS

### 24 Hour Circuit for Electronic Candle

I'm looking for a simple circuit for a 24 hour electronic candle that uses very little power. The candle would drive a single LED. It would run for x hours (say five), then turn off; 24 hours after it was first activated, it would automatically turn back on for the predefined time.

I've found several ideas, but most of them surrounded the 555 chip which has a very limited time frame.

**#11101** **Scott Lapp**  
Simi Valley, CA

### Fluke Scope and RF

I've had a Fluke 99B Series II scopemeter (100 MHz) for a number of years and it works great.

I've started working with amateur radio and would like advice on using this scope to measure RF. I think I need an RF probe. I currently have the set of 10:1 probes that come with the scope.

Can the scope — using the proper probes — be used at the actual antenna feed output from the transceiver?

**#11102** **Jerry Lopez**  
Georgiana, AL

### Probing Question

I am going to build two EHT measurement probes: one at 800 M ohms and the other at 45 G ohms. I will also use a 3140 op-amp or a LM358 op-amp, but need a schematic of the components around the op-amp so that I can change the impedance of the EHT measurement probe and use it with either a multimeter or oscilloscope to check the output of the flyback voltage and signal valves.

Russell Kincaid was kind enough to show me how to get a 10K and 25K sign signal out of a signal generator and an amp to power a flyback for my project, for a sign output from the flyback.

Also, I have a Conar Model 251 oscilloscope 1Q MHz. Can anyone point me to a website that has the valve of the fuse for this scope and maybe a manual?

**#11103** **James New**  
Jacksonville, FL

### Part Identification and Availability

We are repairing printed circuit boards, but cannot locate schematics. We are looking for 32-pin microcontrollers. ID 3s are 14345 with 9122 listed below. That's it. Also, bypass capacitors and holders, U-3A 99X. No manufacturer logos. Have tried obsolete part vendors. No luck. Can anyone help?

**#11104** **Glenn Fischer**  
GA

### Using Up Batteries

With so many devices we use today having a power regulator in them, our batteries become ineffective before they really run out of power. For instance, a digital camera will use fresh alkaline batteries for a very short time. What can be done with these batteries that have plenty of life in them, but not enough to get past the power regulator? Is it possible to blink an LED until there is like half a volt or less in each battery? What interesting things can these "dead" batteries do until they are truly dead?

**#11105** **Rick Montzka**  
Anoka, MN

## >>> ANSWERS

**[#6106 - June 2010]**

### Remote Start

*I am buying my wife a car, but she will not get the garage. So, I agreed to*

*buy her a remote start. I have looked around for one with a clock that will start the car every weekday. So far, no luck. I'm thinking one could program a PIC to start the car like at 8:30 am for 15 minutes, except Saturday and Sunday. Of course, with an override switch for vacations. Any ideas?*

**#1** I'm assuming this is only to happen when the car is home.

The Idec Smart Relay would be perfect; [www.idec.com/usen/products/Catalogs/SmartRelay/SmartRelay.html](http://www.idec.com/usen/products/Catalogs/SmartRelay/SmartRelay.html) IDEC offers a software package that you can test the logic. It has a built-in clock/calendar with automatic daylight savings time. The demo package can be used with or without a relay for 15 days.

If you use the 24 VDC version, you would have DC power available; you'll need some DC power for the remote interface. An OptoFET is a really reliable interface across any remote button. Per your suggestion — make it start the car at 8:30 and turn it off at 8:45 — two outputs are needed. One for OFF and one for ON. One input would be used for Enable/Disable.

**Ron Dozier**  
Wilmington, DE

**#2** I put an electric engine heater on the car. That was more economical than the gasoline to warm up the car.

Check if a block heater can be ordered when buying a new car. Block heaters that go in place of a frost plug can be ordered from an auto parts store like NAPA. There are also electric heaters that can be connected with hoses.

A small block heater can be

All questions AND answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving technical problems. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted

by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

*Always use common sense and good judgment!*





almost no problems with it.

**Ray**  
via email

**#2** The least expensive system to program a PIC16F876A is just about free, if you have a reasonably well-stocked parts box and a computer with an RS-232 serial port. The programmer circuit in **Figure 1** was designed by Ralph Gable, WA2PUX, and appeared in the August 2003 issue of *QST Magazine*. It is based on the so-called "JDM" programmer. However, the schematic in that article contained several errors, so I have redrawn it. One advantage of this circuit is that it works with serial ports that don't meet the RS-232 voltage standards. The circuit requires a clean, stable 13 volt supply from an adjustable benchtop power supply, or you can add an LM317 adjustable regulator to the circuit to supply this voltage. Connect the "flagged" wires in the circuit to the appropriate pins on a socket for the PIC and you're ready to go. This programmer will work with many different PICs, not just the '876. On the software side, download the free trial version of PICBASIC PRO from [www.melabs.com](http://www.melabs.com) to write your programs. To load the programs into the PIC with this programmer circuit, I use IC-Prog 1.05 which is a freeware application available at [www.ic-prog.com](http://www.ic-prog.com). It has worked well for me in both Windows 98SE and XP environments.

**Dan Gravatt**  
Lawrence, KS

#### **[#7101 - July 2010] Measuring Frequency**

*I'm looking for a simple solution that measures the frequency of a pulse (.5 Vss). It does not need to measure higher than 1 kHz. Is there anything out there off-the-shelf or a kit; a small board with an LCD display?*

If "discretion is the better part of valor" then consider these ideas. Obtain a digital voltmeter that measures frequency, as well as the usual parameters. Alternatively, obtain a digital storage oscilloscope that is a plug-in to a PC. Its math function

usually includes the measurement and display of the frequency of a waveform. Either will be a welcome addition to your electronic capability. Start with a search of the advertisers in this magazine. Jameco Electronics has an impressive array of DVMs that measure frequency, as well.

**William A. Hanger**  
Churchville, VA

#### **[#7103 - July 2010] Servo Motors**

*I am building a kinetic sculpture. I have a 5' wide plywood disk that weighs 50 pounds. I need to be able to spin the disk anywhere from between 60 to 500 rpm. Once the disk reaches a given rpm, I need the disk to maintain it precisely. Using just a normal AC motor doesn't work because the rpm seems to be constantly fluctuating. I am told that I need a .25 HP servo motor to achieve this. Any other ideas?*

You left many important details out of your question, like the supply voltage you have available and exactly what "precise rpm" means. For most art projects, an adjustable frequency drive controlling a simple AC induction motor is entirely adequate. For under \$400, you can buy a 120 VAC, 1/2 HP drive from Grainger (model 3XA39).

Couple this to a cheap three-phase motor (I cannot recommend one since I don't know your mechanical requirements), and you can either use the up/down pushbuttons on the drive's front panel to control the rpm or fit a remote speed potentiometer. They have other models for 240 VAC input, too.

**Dan Danknick**  
Santa Ana, CA

#### **[#7104 - July 2010] PWM Signal Generator for Camshaft-Pump Control**

*I am looking to do some development work of an injection pump in conjunction with a camshaft signal. I am looking to drive a coil with a resistance of 1.6 ohms (at 20 C), and an inductance at 1 kHz of 1.72 mH. The signal needs to be a (frequency*

*4 kHz) PWM peak and hold type with two parts: a V\_boost and a V\_hold (or V\_batt). V\_boost needs to be adjustable between 30 and 70V, and the current adjustable from 4 to 12A; V\_hold should be adjustable between 6 and 18V. A zener diode should be used to drain the current from the coil when the driver is deactivated; V\_zener should be 28V. The signal out sequence will be based on feedback from a once-per-rev Hall-effect sensor; conversion to TTL would be fine.*

Before you start, please consider a shaft pickup that has more resolution than once per revolution. Unless the engine is to be run at a nearly constant speed or will be accelerated very slowly, the coarse timing suggested will not follow the run-up of a fast-accelerating engine that may double its speed in one or two revs of the camshaft. At least for developmental purposes, use an absolute position encoder or add a shaft digitizer with multiples of 12 outputs along with the once-per-rev pickup. From the higher resolution encoders, you can decode those desired outputs for the two, three, and four lobes.

My experience with processor control of timing of this sort is that the processor ultimately gets busied up with so much other mundane stuff that it cannot accurately and timely do the main job which must be done on a tight schedule.

Other comments are: The peak (pick) circuit can be common to all drivers since their timing does not overlap; and the coil discharge function should be back into the pick supply rather than into a zener.

At 4 kHz and four to 12 amps, there is appreciable energy to waste in the zener. Also, almost the same energy is recovered in the discharge function as is supplied in the pick function (less IR and magnetic losses). The driver circuit — when not active — should keep the coil near ground or at a negative voltage so as to avoid electrolytic or Galvanic action to the copper windings.

**William A. Hanger**  
Churchville, VA



## **AMATEUR RADIO AND TV**

PolarisUSA Video, Inc.	13
Ramsey Electronics, Inc.	22-23
V-Module	30

## **BATTERIES/ CHARGERS**

Cunard Associates	37
-------------------	----

## **BUYING ELECTRONIC SURPLUS**

Jaycar Electronics	53
--------------------	----

## **CCD CAMERAS/ VIDEO**

Circuit Specialists, Inc.	82-83
PolarisUSA Video, Inc.	13
Ramsey Electronics, Inc.	22-23

## **CIRCUIT BOARDS**

AP Circuits	28
Cunard Associates	37
Dimension Engineering	42
Electronic Surplus	9
ExpressPCB	52
PCB Pool	13
Saelig Company, Inc.	33
V-Module	30

## **COMPONENTS**

Canal Kit Corp.	65
Electronix Express	49
Fun Gizmos	37
Jameco	21
Linx Technologies	50
Mouser Electronics	19
V-Module	30

## **COMPUTER**

### **Hardware**

Electronic Surplus	9
Matrix Multimedia	37

### **Microcontrollers / I/O Boards**

Abacom Technologies	30
Basic Micro	33
Bitscope	7
Fun Gizmos	37
I/O Bridge	28
Matrix Multimedia	37
Microchip	3
microEngineering Labs	71

Mouser Electronics	19
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Pololu Robotics & Electronics	20
Solarbotics/HVW	42
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-------------------	----

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Bitscope	7
Command Productions	8
I/O Bridge	28
NKC Electronics	37
PAiA	29
Technological Arts	37

## **EMBEDDED TOOLS**

Mouser Electronics	19
NetBurner	2

## **ENCLOSURES**

Integrated Ideas & Tech.	32
--------------------------	----

## **KITS & PLANS**

Canal Kit Corp.	65
DesignNotes.com, Inc.	37
Images Co.	65
Jaycar Electronics	53
NetBurner	2
NKC Electronics	37
PAiA	29
QKITS	37
Ramsey Electronics, Inc.	22-23
Solarbotics/HVW	42

## **MISC./SURPLUS**

All Electronics Corp.	4
Electronic Surplus	9
Scientifics	43
Surplus Gizmos	70

## **MOTORS**

BaneBots	51
----------	----

Electronic Surplus	9
Jameco	21

## **PROGRAMMERS**

Basic Micro	33
Images Co.	65
microEngineering Labs	71

## **RF TRANSMITTERS/ RECEIVERS**

Abacom Technologies	30
Linx Technologies	50

## **ROBOTICS**

BaneBots	51
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Images Co.	65
Jameco	21
Lemos International Co., Inc.	13
Lynxmotion, Inc.	31
Pololu Robotics & Electronics	20
Robot Power	37
Solarbotics/HVW	42

## **SATELLITE**

Lemos International Co., Inc.	13
-------------------------------	----

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PolarisUSA Video, Inc.	13
Technological Arts	37

## **TEST EQUIPMENT**

Bitscope	7
Circuit Specialists, Inc.	82-83
DesignNotes.com, Inc.	37
Dimension Engineering	42
Jaycar Electronics	53
LeCroy	5
NKC Electronics	37
Saelig Company, Inc.	33
Trace Systems, Inc.	51

## **TOOLS**

NetBurner	2
-----------	---

## **WEB SERVICES**

I/O Bridge	28
------------	----

## **WIRE, CABLE AND CONNECTORS**

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Jameco	21

Abacom Technologies	30
All Electronics Corp.	4
AP Circuits	28
BaneBots	51
Basic Micro	33
Bitscope	7
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Circuit Specialists, Inc.	82-83
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Dimension Engineering	42
Electronic Surplus	9
Electronix Express	49
ExpressPCB	52
Fun Gizmos	37
Images Co.	65
Integrated Ideas & Tech.	32
I/O Bridge	28
Jameco	21
Jaycar Electronics	53
LeCroy	5
Lemos International Co., Inc.	13
Linx Technologies	50
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Matrix Multimedia	37
Microchip	3
microEngineering Labs	71
Mouser Electronics	19
NetBurner	2
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PAiA	29
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PolarisUSA Video, Inc.	13
Pololu Robotics & Electronics	20
QKITS	37
Ramsey Electronics, Inc.	22-23
Robot Power	37
Saelig Company, Inc.	33
Scientifics	43
Solarbotics/HVW	42
Surplus Gizmos	70
Technological Arts	37
Trace Systems, Inc.	51
V-Module	30



## Triple Output Bench Power Supplies



The new CSI3303S & CSI5505S regulated DC power supplies are high reliability, variable DC Power Supplies with built in short circuit and thermal protection. These power supplies are suitable for the laboratory, electronics, communications equipment maintenance, production line, scientific research and educational institutions. Both units are equipped with protection circuits that protect the units from short circuits and over temperature by shutting the unit down for safety. Both units allow independent, serial and parallel mode operation.

### Technical Specifications:

Independent mode: 2 independent 0-30V outputs

Series mode: CSI3303S Output from 0-60V & 0-3A  
CSI5505S Output from 0-60V & 0-5A

Parallel mode: CSI3303S Output from 0-6A & 0-30V  
CSI5505S Output from 0-10A & 0-30V

Both units also provide a 5V fixed output @ 3A

Load regulation: <0.1%+3mV (rating current <3A)  
<0.2% +3mA  
Ripple and noise: <1mVrms 5Hz-1MHz  
<3mArms

Voltage accuracy: +/-0.5%rdg+2byte  
Current accuracy: +/-0.5%rdg+2byte

Display resolution: +/-0.5%rdg+2byte  
Rated output: 5.0V +/-0.1V 3A

### Tracking characteristics

#### Series specifications:

Load regulation: less than 50mV  
Ripple and noise: (5Hz-1MHz) <=3mVRMS

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Load regulation: less than 50mV  
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[www.CircuitSpecialists.com/Aardvark](http://www.CircuitSpecialists.com/Aardvark)

The Aardvark Wireless Inspection Camera is the only dual camera video borescope on the market today. With both a 17mm camera head that includes three attachable accessories and a 9mm camera head for tighter locations. Both cameras are mounted on 3ft flexible shafts. The flexible shaft makes the Aardvark great for inspecting hard to reach or confined areas like sink drains, AC Vents, engine compartments or anywhere space is limited. The Aardvark II comes with with a 3.5 inch color LCD monitor. The monitor is wireless and may be separated from the main unit for ease of operation. Still pictures or video can also be recorded and stored on a 2GB MicroSD card (included). The Aardvark's monitor also has connections for composite video output for a larger monitor/recorder and USB interface for computer connection. Also included is an AC adapter/charger, video cable and USB cable. Optional 3 ft flexible extensions are available to extend the Aardvark's reach (Up to 5 may be added for a total reach of 18 feet!).



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Specifications	DSO-2090	DSO-2150	DSO-2250	DSO-5200 /5200A
Channels	2 Channels			
Impedence	1M 25pF			
Coupling	AC/DC/GND			
Vertical resolution	8 Bit			9 Bit
Gain Range	10mV-5V, 9 Steps			10mV-10V, 10Steps
DC Accuracy	+/- 3%			
Timebase Range	4ns - 1h 38 Steps			2ns-1h, 39 Steps
Vertical adjustable	Yes			
Input protection	Diode clamping			
X-Y	Yes			
Autoset	30Hz-40MHz	30Hz-60MHz	30Hz-100MHz	30Hz-200MHz
EXT1 input	Yes			
Trigger Mode	Auto / Normal / Single			
Trigger Slope	+/-			
Trigger Level Adj.	Yes			
Trigger Type	Rising edge / Falling Edge			
Trigger Source	Ch1 / Ch2 / EXT			
Pre/Post trigger	0-100%			
Buffer size	10K-32K per ch			10K-512KB per ch
Shot Bandwidth	DC to 40MHz	DC to 60MHz	DC to 100MHz	100MHz
Max Sample Rate	100MS/s	150MS/s	250MS/s	200MS/s / 250MS/s
Sampling Selection	Yes			
Waveform Display	port/line, waveform average, persistence, intensity			
Network	open / close			
Vertical Mode	Ch1, Ch2, Dual, Add			
Cursor/Measurement	Yes			
Spectrum Analyzer				
Channels	2 Channels			
Math	FFT, addition, subtraction, multiplication, division.			
Bandwidth	40 MHz	60 MHz	100MHz	200 MHz
Cursor	Frequency, Voltage			
Data Samoles	10K-32K/Ch			10K-1M/Ch





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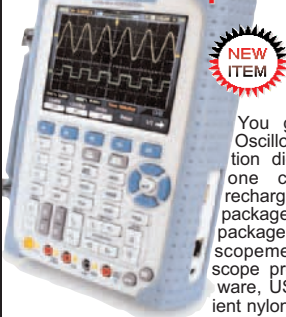
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# GPS



Parallax GPS Module	PMB-648 GPS SIRF Internal Antenna	PMB-688 GPS SIRF Internal/External Antenna	RXM-SG GPS Module w/External Antenna
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Built-In Patch Antenna	Built-In Patch Antenna	Built-In Patch Antenna or optional External (#28502)	Included External Antenna
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Custom ASIC GPS Controller	SiRFstar III GPS Controller		
Tracks up to 12 satellites	Tracks up to 20 satellites		
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Baud Rate: 4800 bps	Baud Rate: 4800 bps (Optional 9600, 19200, 38400)		Baud Rate: 9600 bps (Optional 4800, 19200, 38400, 57600)



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